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THE

HAND BOOK

OF

CHEMISTRY.

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1843.

TO THE READER.

I HAVE laboured in the following compilation to convey to my readers as many facts as it was possible, by the most careful condensation, to comprise within the compass prescribed to me. In the volumes on Animal and Vegetable Physiology, those portions of organic chemistry will be examined which it was not possible to include in this.

To the student who wishes for further information on Chemical subjects I would recommend the "Elements of Chemistry" by Professor Kane, and also the works of Professors Graham, Daniell, Faraday, and Thomson, and Professor Gregory's edition of "Turner's Elements."

W. RALEIGH BAXTER.

CONTENTS.

CHEMISTRY.

The object of Chemistry is to discover the elementary constituents of every compound body that can come under our notice; to examine into the laws which regulate the union or separation of these constituents; to observe their action upon each other, and to define the results consequent upon that action, as well as to mark the phenomena accompanying it.

Fire, air, earth, and water, constituted the elementary principles of the early philosophers. Sulphur, spirit, salt, oil, and earth, were subsequently regarded as the elementary principles. We are indebted to Lavoisier for the first clear enunciation of the true philosophy of the science; the object of which he stated to be, in the first instance, to resolve the various compound bodies found in nature into others which resist our power, and which are termed *undecompounded*, or *simple substances*, without, however, determining that they are elements; for the progress of science enables us to decompose bodies which had been looked upon by our predecessors as simple: and secondly, to effect the recombination of these simple, or apparently simple bodies, either in the same proportions, and thus reproduce the natural compound bodies, or in new proportions, and thus give origin to bodies hitherto unknown. The first of these operations is termed *analysis*, the second *synthesis*, and every chemical process is conducted according to the principle of one or the other of the two; and it sometimes happens, that both are effected successively or at the same time. Chemistry, however, has objects of a more useful and elevating character than can be said to exist in the mere consideration of the laws which regulate the composition of compound bodies; such, for instance, is its application to the arts and to medical science.

The precise etymology of the word Chemistry is unknown: we find it first as χημεία, denoting the art of making gold, as attempted by the Egyptians and others, who for five centuries followed up the delusive notion, to the prosecution of which we are indebted for many useful, though accidental results. From Alexandria it passed across the Mediterranean in the usual path of literature and science to Greece, and from the Greeks it was taken up by the Arabians, who giving it a prefix peculiar to their tongue, lent it to the languages of modern Europe under the name of *Alchemy*, which finally resolved itself into *Chemistry*.

GRAVITY AND COHESION.

These are the physical forces which are of the greatest value in determining the peculiar characters of bodies; they differ widely in principle and are applied to distinctly different purposes. Gravity is common to matter in every form. It is exerted at all distances proximate and remote, and forms the bond of union in our planetary system. Acting on the mass, it is a measure of the quantity of matter existing in any body, and what is popularly denominated *weight* is merely the gravitating force exerted by the body weighed.

Matter is indestructible; we cannot annihilate it by any means. The quantity of matter remains the same though it may have passed through the most complicated processes, and may have assumed various phases. Thus the combined weight of bodies, which are the result of decomposition, is exactly equal to the weight of the original body whence they were derived or separated by chemical action.

Different bodies, occupying a similar extent of space, have different quantities of matter. Bodies are said to be *dense,* in proportion to the quantity of gravitating matter they contain in a given volume, and when any one body is taken as a standard and the density of others is taken as compared with it, and duly calculated in numbers, what is called the *specific gravity* of these bodies is obtained. This being almost invariably uniform in like bodies, furnishes an important fact in their description, and a valuable means of recognising them. When we can accurately measure the volume of any body, its specific gravity is a matter of easy discovery: if we take a bottle made to hold an ounce (480 grains) of water, it will hold 343 grains of sulphuric ether, or 885 grains of sulphuric acid. Taking water as the standard, and assuming its specific gravity to be 1000, the specific gravities of the other fluids may be proportioned thus:—

Water	480	1000
Ether	343	715
Sulphuric acid	885	1845

To save trouble the bottles in common use for this purpose are made to contain 1000 grains of distilled water, and when filled with any other fluid the weight gives at once the specific gravity. The specific gravity of a gas may be found by an analogous process. Instead of a bottle we use a glass globe, with a stop-cock, made to hold from 20 to 30 cubic inches of air. The air having been removed by means of the air-pump, the gas to be weighed is admitted in its stead, in a state either of perfect dryness, or quite saturated with moisture. The volumes of air and gas being equal, it is only requisite to find the relative weights, which when compared will give the specific gravity of the gas. Suppose the globe full of air to weigh 656 grains, when exhausted to weigh 647·5, and having received 28 cubic inches of carbonic acid gas, it weighs 660·3 grains.

The air is found to have weighed 8·5 grains, and the same volume 28 cubic inches of the gas, to have weighed 12·8, the densities are as 8·5 to 12·8, and air being taken as 1000, the specific gravity of the gas is $\frac{12{\cdot}8}{8{\cdot}5} \times 1000 = 1{\cdot}506$.

In taking the specific gravity of solids, an instance is furnished of the hydrostatic law, by which if a solid be plunged into a fluid the solid will lose as much of its weight as is equal to the weight of a similar bulk of the fluid. To ascertain the weight of the quantity of water equal to the bulk of a solid, we have only to weigh the solid first in air, and then in water; in the last case it will lose some of its weight. The weight required to restore the equilibrium will be found equal to that of the water displaced by the immersion of the solid, and which was equal in bulk to the solid. Supposing the solid to lose by immersion one ounce in weight, the weight of the same bulk of water was one ounce, and assuming the weight of the solid in air to be six ounces, it is clear that it weighed six times as much as the weight of its own bulk of water. The specific gravity in this case is marked as 6. The weight of water is taken as unity, and for the convenience of fractional computation is set down as 1000. The volumes of bodies vary as their temperature and the pressure upon them vary, and in taking air and water as the standards, we assume the temperature to be 32 of Fahrenheit's scale, and the pressure to be equal to 30 inches of mercury in the barometer. The operation of taking specific gravities, especially of gases, is one requiring very delicate manipulation, a precise description of which it is scarcely possible or necessary to give, where general principles only are dealt with.

DIVISIBILITY OF MATTER.

THE question as to the limited divisibility of matter, is one that has occupied the attention of philosophers in all ages. No experiment of mere mechanical division has served to solve this problem; for, using every means at our disposal, we can produce no particle so small as to be incapable of further division. The extreme divisibility of matter may be demonstrated in many ways. In the gilding of silver wire, one grain of gold is extended over a surface of 1400 square inches, and as the gold upon the millionth part of a square inch is distinctly visible with the microscope, it is deduced that gold may be divided into particles of $\frac{1}{1\cdot400\cdot000\cdot000}$ of a square inch, and still possess the general physical characters of a mass of the metal. Many examples of this nature may be given; of these the following may be regarded as one of the best: Dissolve a portion of silver of 0·01 of a cubic line in size, in nitric acid, and it will render milky 500 cubic inches of a solution of common salt. In this case the size of each particle of silver is rather less than a billionth of a cubic line, and it is computed that to reckon with a watch a billion of seconds, counting day and night, would require above 31 years. Organic matter furnishes us with even more striking evidence of this divisibility; one pound of flax has been spun into a thread of 1432 miles in length. Even this thread, though of extreme tenuity, must have been made up of more than one fibre, each containing a complex structure. The minute structures demonstrated by the microscope, are of a character still more astounding. These facts, however, merely prove the great divisibility of matter, and the belief in its finite divisibility now prevails amongst philosophers generally. Wollaston and Faraday have instituted experiments to prove limited divisibility. We know that our atmosphere does not extend beyond a distance of 45 miles from the earth's surface. The particles of air, according to Dr. Wollaston, are balanced between their mutual repulsion and the general attraction toward the earth; now if these particles were divisible to an infinite degree there would be an infinite source of repulsive power, and at a certain distance this repulsion overcoming the gravitating force, the atmosphere would spread into space, and being attracted to the other planets in proportion to their masses, would form around them atmospheres easily recognisable from their density. It is an established fact, that no such atmospheres exist, and thence Wollaston deduces, that the force of repulsion must have a limit, and that the number of repelling particles cannot be infinite. Faraday drew similar conclusions from the fact, that bodies in evaporating form atmospheres above their surface of definite extent. But it is by no means conclusive that the particles of air in a given space are not infinite, because there is a limit to its elasticity.

ATTRACTION AND REPULSION.

SETTING aside the question of divisibility, all masses of matter may be regarded as consisting of a number of particles. Upon these two distinct forces act. The first is attractive, and is termed the attraction of aggregation, or cohesion; the second is of an opposite character, and is termed repulsion. The physical characters of all substances are owing to the relative influence of these forces. If one were to act unopposed, unconquerable hardness would everywhere exist; if the other force entirely prevailed no form of matter but the gaseous could exist. The results of the action of heat are for the most part identical with repulsion. On the surface of the planet mercury, the metal of that name would be converted into a gas, and the metals found here in a solid form, would there constitute molten seas. On the other hand, the cold of the planet Herschel, which enjoys only 1-400th part of the heat that our earth derives from the sun, would convert bodies which exist naturally here as liquids or gases, into masses of extreme density. The conditions of matter resulting from the influences of cohesion and repulsion are the solid, the gaseous, and the liquid. The first existing where cohesion preponderates, the second where repulsion acts uncontrolled, and the third where the forces are balanced, and the particles of matter, under their combined action, move freely over each other. Most bodies are capable of assuming these three conditions by the increase or diminution of heat. By the application of heat a solid may be converted into a liquid, and by a further increment into a gas. The converse of the rule also will apply. We have not, however, been able to freeze alcohol, and charcoal has not been melted.

Cohesion acts at insensible distances; fragments of any metal placed in close proximity evince no disposition to unite, but if pressed together an union may occur. Plates of glass will adhere strongly if submitted to sufficient pressure, and if the clean-cut surfaces of two pieces of lead be pressed together it will require considerable weight to separate them. Cohesion gives to small portions of fluid the globular form, and also causes the adhesion of fluids to solids, except in cases where the cohesive force in fluids is sufficiently powerful to overcome this tendency, as when the finger is dipped into mercury. The phenomena of capillary attraction are the result of this cohesion of fluids to solids.

Bodies are said to be *compressible,* when by the application of external force their volumes may be reduced in size; if, upon the removal of the force, they reassume their former shape, they are said to be *elastic.* Few bodies are perfectly elastic, and none entirely inelastic. The influence of pressure on solids and liquids is limited. The particles of gases being at greater distances from each other afford a considerable amount of compressibility, and the law in reference to gases is, that their volumes vary inversely as the pressure upon them. Thus, suppose a gas to measure 100 volumes under a pressure of 20 lbs., with a pressure of 80 lbs., the volume becomes 25; with a pressure of 40, a volume of 50; and so on. In all these cases due regard must be had to atmospheric pressure, as alterations are constantly occurring from this cause.

The pressure exercised by the air is measured by the barometer, in the tube of which, a column of mercury opposes the pressure of the atmosphere, and varies in height as the atmospheric pressure varies. The height varies from 28 inches to 31, the average being 29·8 inches. For convenience the whole number 30 is taken, and when volumes or specific gravities are stated, this pressure is understood. If the barometer do not stand at 30 inches, a calculation may be made by which the volume may be calculated according to that standard. Thus, if we have 4·54 cubic inches of nitrogen gas, the barometer standing at 28·5 inches, V denoting the volume at 30 inches, we say, $V : 28{\cdot}5 :: 4{\cdot}54 : 30$, or $V = \frac{28{\cdot}5}{30} \times 4{\cdot}54 = 4{\cdot}313$. The weight of 100 cubic inches of nitrogen at 30 inches being known, the weight of 4·313 can be obtained with facility. To the rule of the volume being inversely as the pressure, there are exceptions. In many cases where the pressure is very great, the cohesive force is brought into play, and the volume decreases with a rapidity disproportioned to the rule above stated. Many gases have been reduced to the liquid state, by a pressure differing in amount for each gas. The following list will supply examples:—Nitrous oxide is reduced to a liquid, by a pressure of 44 atmospheres, or 660 pounds to the inch; carbonic acid, by 36 atmospheres; muriatic, by 24; sulphuretted hydrogen, by 15; ammonia, by 5; cyanogen, by 3; sulphurous acid, by 2. Oxygen, hydrogen, and nitrogen, have been submitted to a pressure of 800 atmospheres, without being at all made to deviate from perfect elasticity; but it is reasonable to suppose, that if we could only exercise sufficient pressure, they too might be rendered fluid.

Bodies are said to be *soluble* when the cohesion between their particles and those of any fluid is greater than the cohesion existing between the particles of the solid. This solubility differs in degree in different bodies. Common salt is soluble in water, chalk is not;

but a link of connexion is formed between these extremes, by bodies possessing solubility to a greater or less extent; generally speaking, solubility is increased by the application of heat. During this process of solution cold is usually produced, though sometimes a remarkable elimination of heat occurs, as when a salt deprived of the water chemically combined with it, is dissolved. In this case, a portion of the water of solution may be supposed to combine with the salt, and the heat resulting from this combination will be sufficient to counteract the cold produced by the solution.

When a fluid has overcome the cohesion of a solid to the full extent of its power, it is said to be saturated,—that is, the cohesive forces of the two are balanced.

CRYSTALLIZATION.

The cohesive power of solids is frequently exerted when they are in a state of solution, and the solids resolve themselves into certain forms characteristic of the substances to which they belong, and these are called *crystals*. When a substance is more soluble in a hot fluid than in a cold one, a saturated hot solution may be made, and the excess of the solid in this case will crystallize upon cooling. Crystals, however, are not the peculiar result of solution, for most bodies when cooling after a state of fusion assume a crystalline appearance. This may be exemplified by the following experiment:—melt some sulphur in a cup, and when a crust has been allowed to form on the top and sides by cooling, make two holes, and pour the fluid portion out of one opening while the air is entering at the other; upon breaking the vessel the contents will be found to have formed beautiful crystals. Many substances when solidifying from a state of vapour assume the crystalline form, as benzoic acid, corrosive sublimate, &c. When the same body is crystallized in two ways, it assumes different shapes, and is called *dimorphous*. Slow cooling or spontaneous evaporation produces large and regular crystals, and crystallization takes place more rapidly in a pan with some roughness at the sides than in a smooth one. Threads are hung in the syrup when sugar-candy is being made to promote the crystallization; and a crystal of the salt held in solution is frequently dropped in to form a nucleus, round which other crystals aggregate. If more than one salt be held in solution the crystallization of any particular one may be promoted by dropping in a crystal of the salt, the crystallization of which, from the solution, is desired. Take, for instance, a solution of equal parts of nitre and Glauber salt, and place it in two dishes; by placing a crystal of nitre in one, similar crystals only will be produced, and crystals of Glauber salt only will be produced by dropping in a crystal of that salt. A number of salts in solution may be separated also by their relative solubility. Thus, during the evaporation of sea-water common salt only will be crystallized, while the liquor boils away; remove it from the fire and Epsom salt will be formed; let this be taken away and the mother-liquor, as the fluid is called, from which crystals have been obtained, will still be found to contain chloride and iodide of magnesium. Saturated solutions sometimes remain uncrystallized though reduced to a low temperature; agitation, or the introduction of a crystal in such cases will produce sudden crystallization, and often solidification. According to a general law, heat is evolved when a fluid or vapour becomes solid, and this rule obtains in all cases of crystallization. Light also is given out. The action of light has a very sensible effect in promoting crystallization, as will be seen by partially exposing a solution to the light, when the process will be almost entirely confined to that portion of the solution thus exposed.

Each crystallizable substance has a form of crystal which characterises it. This is called the primary form; and when this is departed from any different shape is called a secondary form. Carbonate of lime has been found in above six hundred forms, all resulting, however, from the primary rhombohadron. The departure from the primary form is caused by a greater deposition of particles on one side than on another, and the change usually occurs when an edge or angle is replaced by a plane surface. A cube is one of the simplest forms of crystals (fig. 1). Substitute plane surfaces for the edges and a secondary form (fig. 2) will be produced. Replace the solid angles by planes and we have another shape (fig. 3); let these changes occur simultaneously and a still more complex figure is made (fig. 4). Replace the edges of the cube until every trace of the original planes disappears and the rhombic dodecahedron (fig. 5) is produced; and if the solid angles be replaced by planes to a similar extent, a regular octohedron will be formed (fig. 6). When depositions take place upon the faces of a crystal, the cohesion between the particles of each

Fig. 1.

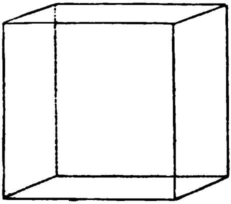


Fig. 2.

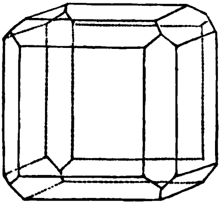


Fig. 3.

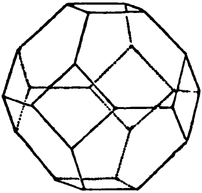


Fig. 4.

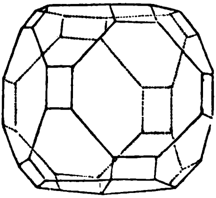


Fig. 5.

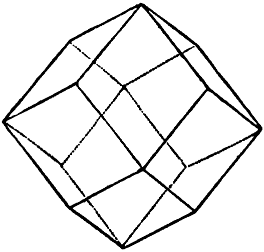
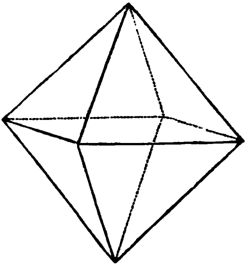


Fig. 6.



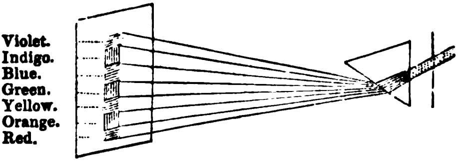
layer is greater than the cohesion between the layers. These layers may, therefore, be separated, and the direction in which this separation takes place is termed the *cleavage*, which serves to determine the primary form of the crystal under examination. All forms of crystals may be reduced to a few classes, by assuming them to be constructed around certain axes. Dr. Kane, in his "Elements," adopts six systems based upon this theory, to one or other of which systems every crystal is referrible. When crystals are the result of accidental circumstances they are called *pseudomorphous.* When solutions of different kinds are mixed, modifications of form in the crystals will occur. In this case no chemical combination exists, as the union is merely mechanical, and the quantity of each distinct body in the crystal is indefinite. The form of crystal is intermediate between the forms of the bodies when they are separate. To cause different bodies thus to crystallize together it is necessary that they should belong to the same system of crystals, and the forms also must closely resemble each other, thus offering a remarkable analogy to a law of organic nature.

CHEMICAL PROPERTIES OF LIGHT.

LIGHT proceeds from luminous bodies in straight lines. When a ray of light falls upon any surface it is either bent back or enters into the substance upon which it falls. The angle at which it falls upon any reflecting surface, and the angle at which it is reflected from it, are always equal. When light passes into the substance of a body it is said to be *absorbed*, and becomes invisible. When it passes through a body the body is said to be *transparent*. Bodies through which light cannot pass are called *opaque*, and this opacity is of two kinds,—when the light is absorbed the body upon which it falls being black, and when the light is reflected and the body is white. When the light is partly reflected and partly absorbed, varieties of colours are visible peculiar to the opaque bodies whence they emanate. When a ray is neither absorbed nor reflected it is refracted; that is, upon entering the refracting body, its direction is altered. Thus, an oar partly immersed in water appears bent at the surface of the water. The substance through which light moves is called a *medium*, and as this is more or less dense the refraction is greater or less. Reflection, refraction, or absorption, does not absolutely occur. Every body reflects light to some extent, and light passes through no body without undergoing some absorption. In general, light falling upon any body is partly reflected, partly absorbed, and partly transmitted, the proportions depending upon the nature of the body. Light is transmitted from luminous bodies at the rate of 195,000 miles in a second, the light of the sun arriving at the earth in the space of eight minutes. The velocity of light is altered in passing through media of different densities; in general, the velocity is diminished in proportion to the density of the medium. Inflammable bodies usually possess high refractive power. This fact led Sir Isaac Newton to regard the diamond as combustible, and to prophesy that water would be found to possess an inflammable element. Certain bodies, however, which are not at all combustible possess high refractive powers.

White light is composed of seven distinct colours. These are separable by a prism of glass placed before a ray admitted through a slit into a darkened chamber.

In passing through this prism the rays are refracted, and when thrown upon a screen beyond the prism are found to have different refrangibilities. The colours in the order of refrangibility are as follow: violet, indigo, blue, green, yellow, orange, red; the violet being the most, the red the least, refrangible. The accompanying diagram will give a clear idea both of the method of decomposing the solar light and of the results.



Beyond the violet ray another ray has been recently discovered by Herschel, of which he assumes the colour to be lavender. This ray cannot be a more subdued hue of violet, as it remains unchanged when concentrated by a lens. Of the seven generally received prismatic colours three only are deemed primary,—blue, red, and yellow, orange being a mixture of the extremes of the red and yellow, green of the yellow and blue, and indigo and violet of blue with red in excess. Blue, red, and yellow are spread over the whole surface of the spectrum in unequal quantities, for, if equal, no decomposition would take place. The colours of bodies depend upon the relative proportions of light absorbed and transmitted by them. An object seen by reflected light generally presents a different colour from the same object seen by transmitted light, for it often reflects to a considerable extent the light which it does not transmit. Solution of litmus by transmitted light has a reddish purple hue, and when seen by reflected light a pure blue. A ray of light is said to be polarized when it is reflected from any surface at a particular angle and acquires certain properties which it had not previously. If the ray be made to fall upon a second reflecting surface, the effect will vary according to the position of the plane of the second reflected ray. The reflection is complete if it be in the same plane as the first; but, if at right angles, there is no light reflected, the quantity of light reflected in intermediate positions varies with the angle formed by the second with the original plane. In this case light is said to be polarized by reflection. Polarization may be effected also by other means.

Light is usually associated with heat; the sun is the common natural origin of both; and, in most cases, when light is produced artificially, it is connected with heat. Heat and light, however, are perfectly distinct and independent powers, and are separable from each other. Bodies become luminous when heated, and friction is also a source of light, as when two pieces of sugar are rubbed together. Many bodies when exposed to the sun's light, after being made red hot, acquire the power of emitting light for some time in the dark, having probably absorbed the light. Such bodies are called *phosphorescent.* Carbonate of lime is an example. Organic substances phosphoresce in the early stages of decay; fish, for instance, and wood. This phosphorescence is owing to a slow process of combustion. For this the presence of atmospheric air or of oxygen is requisite, and it is retarded or promoted by all the means which influence the chemical action of air upon organized bodies. The elimination of light from the glow-worm, the firefly, and from marine zoophytes, appears to be not so much a product of vital action as the result of a slow combustion of some peculiar animal secretion.

Some substances are remarkable for the facility with which they are decomposed by the action of light: amongst them may be named the salts of silver, of gold, of platinum, and some salts of mercury. Vegetable and animal substances, in a vast many cases, are strongly affected by the influence of the solar rays. Light is absolutely requisite for the development of some colours, while most are quite destroyed by its action. This, which is termed the chemical property of light, is found to exist at the violet extremity of the prismatic spectrum, and is exercised in the greatest intensity beyond the luminous space, including the lavender ray of Herschel. It has been thought that the red rays of the spectrum were possessed of chemical properties, opposed to those of the violet. Of this no conclusive proof exists. It is certain that in all solar light there exist three distinct sets of rays, one possessing luminous properties, another radiant heat, and a third chemical influence, without any admixture of the former two.

HEAT.

THAT all bodies, solid, liquid, and aeriform, contain heat, is a matter of easy demonstration. Strike a piece of soft iron with a hammer for some minutes and it will become hot. A common mode of producing fire amongst savage nations, is by the friction of two pieces of dry wood, and even if two pieces of ice be rubbed against each other they will melt. Considerable heat is evolved by the mixture of sulphuric acid and water. Heat also exists in air, as may be demonstrated by a simple experiment. Take a brass tube, with a piston made to fit it closely, so that no air may escape, place a small bit of dry agaric (vegetable fungus) in the tube, and by a smart stroke upon the piston compress the air in the tube suddenly, and the heat evolved will be sufficient to set fire to the agaric. By a mixture of phosphorated hydrogen and oxygen, flame is immediately produced. In all phenomena resulting from chemical action heat exerts a most important and general influence. The forces of repulsion and heat, generally speaking, are similar, or the one is a direct result, in most cases, of the other.

Expansion, or the removal of the ultimate molecules of matter to a greater distance from each other, is a consequence of heat. In the case of gases this expansive force is opposed by no cohesive power, and certain increments of heat produce a like increase of volume in every instance. The expansion which takes place in solids and fluids is modified by the cohesive force of each, and the degree of expansion is, of course, liable to differ, each separate body having a capacity peculiar to itself. The successive quantities of heat which bodies receive are estimated by the thermometer and pyrometer.

The word *temperature* has reference only to the expanding power existing in a body, and not to the amount of heat it may contain. If any number of bodies produce the same degree of expansion when applied to the thermometer, we say they have the same temperature, without meaning to note the exact quantity of heat each may contain. The thermometer and pyrometer are, therefore, measures of temperature and not of heat. To calculate the expansion of gases the " air thermometer" is used. The fluids whose expansion is generally resorted to, to measure temperature, are alcohol and mercury, their expansion being much less than that of air. Alcohol, in being raised from the melting point of ice to its own boiling point expands $\frac{9}{700}$, air, under similar circumstances, $\frac{32}{100}$, about $3\frac{1}{2}$ times as much as alcohol. Mercury, in being raised from the melting point of ice to the boiling point of water, expands about $\frac{18}{100}$, about $\frac{1}{20}$ of the quantity of air. Alcohol, as it cannot be frozen, is well calculated to measure low temperatures. Mercury has a wide range of temperatures, as it requires an intense cold to freeze it, and boils only at a red heat; its expansion, also, in the thermometer is in due proportion to that of the tube, and its indications are, therefore, accurate.

In making a thermometer it is absolutely necessary that the caliber of the tube should be perfectly equal, for otherwise the degrees of expansion could not be measured with accuracy. By moving a small quantity of mercury up and down the tube, it will be easily discovered if any inequality exist, as, in that case, it will not occupy similar lengths of space. A proper tube being found, one end is closed, and a bulb blown on it; a bulb is also formed at the open end, the interval being longer than the instrument is intended to be, the entire being heated, the open end is plunged into pure recently boiled mercury and allowed to remain till cold. The expanded air within the tube contracts, and mercury is forced into the space to supply its place by the pressure of the external air. This process is repeated until the bulb at the closed end is filled. When sufficient mercury has been introduced the open end of the tube is closed to exclude dust, by a little sealing-wax, and the tube is allowed to cool with the first bulb down. When it has completely cooled it is again heated to the highest degree which it is intended to indicate, and the flame of a blow-pipe being directed upon the second bulb it is melted and permanently closed. Between this end of the tube and the surface of the mercury a vacuum exists when the mercury and tube have cooled. A scale must now be applied. The simplest scale is called the centigrade scale, which is in general use in France and Germany. This ranges from the melting point of ice which is marked 0°, to the boiling point of water, which is marked 100°. The scale in use in this country is that of Fahrenheit, upon which the freezing point of water is marked 32°, and the boiling point 212°. The lowest temperature he could find was by a mixture of snow and salt; and this he regarded as zero, erroneously thinking that below this point bodies were destitute of all heat. Another scale is in use, but is not so popular as either of the other two. This is the scale of Reaumur, upon which the melting point of ice is marked 0°, and the boiling point of water 80°. In making a scale, it will be necessary to remember, that water when perfectly at rest, and in smooth vessels, may be reduced to a much lower temperature than 32°. Ice, in all cases, however, melts at 32°, and the bulb may be plunged into a mixture of ice and water. The first fixed point on the scale may be thus accurately marked. To ascertain the second it will be necessary to consult the barometer, as the boiling point of a fluid varies with the degree of pressure upon its surface. If the mercury in the barometer do not stand at 30 inches, a correction must be made for any difference of height at the time the boiling point is taken. In taking the boiling point of water, it must be made to boil in a metallic vessel, as water in glass or porcelain vessels has its boiling point raised. If the thermometer be intended for chemical purposes, the bulb and a small portion of the stem only should be immersed. The two fixed points being thus determined, the interval is to be divided into 180 equal parts, and 32 parts of similar length to these must be counted downward from the melting point of ice to indicate the zero. As we can obtain a much lower degree of cold than Fahrenheit did, we count downward, prefixing the — minus sign, thus: —39°, or 39° below zero is the freezing point of quicksilver. The centigrade scale is constructed on a similar principle. Before constructing the scale the tube should be set aside for some weeks, as from the vacuum existing above the mercury the bulb yields a little to the pressure of the atmosphere, and pushes the mercury higher up in the tube. A degree of Fahrenheit is equal to $\frac{5}{9}$ of a degree in the centigrade scale, and to reduce any degree of the centigrade to a corresponding one of Fahrenheit, it is to be multiplied by 9, and divided by 5. To reduce from Fahrenheit's to the centigrade scale, multiply by 5, and divide by 9. In reducing from the centigrade to Fahrenheit's scale, we must add 32°, the 0° of centigrade being equivalent to 32° of Fahrenheit. In reducing Fahrenheit's to the centigrade, we subtract 32°. Thus 167° of Fahrenheit correspond to 75° centigrade; for

$$167^\circ - 32 = 135, \text{ and } 135 \times \tfrac{5}{9} = 75^\circ$$

To reduce 65° centigrade to Fahrenheit, we calculate

$$65^\circ \times \tfrac{9}{5} = 117^\circ \text{ and } 117^\circ + 32 = 149^\circ$$

of Fahrenheit. The scale of Reaumur is to the centigrade as 4 to 5; and reductions may be made on a similar principle. The range of temperature that may be calculated with the mercurial thermometer is from 39° to 630°. The means of estimating temperatures above this point are not so certain as for lower temperatures. The instruments constructed for the purpose of determining higher temperatures are called pyrometers. Of these the most recent and the best is the invention of Professor Daniell; the indications in this instrument are made by the excess of expansion of an iron bar over the expansion of a black lead case, in which it is enclosed. With this instrument Professor Daniell has determined the freezing points of many important metals, and also several temperatures at which remarkable phenomena occur; the subjoined list of temperatures calculated by Fahrenheit's scale will be found interesting if not useful:

—135°	The greatest cold that can be produced.
—121°	The solid compound of alcohol and carbonic acid melts.
—91°	The greatest cold that can be produced by ordinary freezing mixtures.
—60°	Greatest cold observed in the arctic regions.
—58°	Temperature of the planetary spaces.
—47°	Sulphuric ether congeals.
—45°	Nitric acid congeals.
—39°	Mercury congeals.
1°	Oil of vitriol freezes.
14°	Oil of turpentine freezes.
20°	Wine freezes.
25°	Blood freezes.
32°	Ice melts.
36°	Olive oil freezes.
98°	Blood heat.
108°	Phosphorus melts.
174°	Alcohol boils.
201°	Rose's metal melts.

211°	Newton's metal melts.
212°	Water boils.
218°	Sulphur melts.
662°	Mercury boils.
810°	Antimony melts.
980°	Red heat.
1141°	Heat of a common fire.
1869°	Brass melts.
1873°	Silver melts.
1996°	Copper melts.
2200°	Gold melts.
2786°	Cast-iron melts.

EXPANSION OF GASES.

The precise amount of dilatation in gases was first ascertained by Dalton and Gay Lussac about the same time. From the experiments conducted by these philosophers, and also by Dulong, it appears, that 1000 volumes of air when heated from 32° to 212° became 1375°, and that the change was in proportion for higher or lower temperatures. The results obtained by Dalton and Gay Lussac, however, have been submitted to rigid examination by Rudberg, who has found that this rate of expansion is too great, and that a volume of air in being heated from 32° to 212° expands from 1000° to 1365°. In every experiment upon gaseous mixtures, the expansion of air must be included: for, as all gases expand alike, and as the vapours even of bodies such as camphor and corrosive sublimate, which are least volatile, expand, in their elastic form, as gases do, their volumes are corrected for temperature and pressure in the same manner. In determining the specific gravity of a vapour, it is customary to reduce it to the same standard as that of gases, namely, air at 32°; even when the substance at 32° may produce no sensible vapour, for it is assumed that the vapour in cooling to 32° should be governed by the same law as common air. If we have 155 cubic inches of hydrogen gas at 142° F.

and that we wish to know the volume at 32°, we say, that as 142° is 110° above 32°, the 155 cubic inches are equal to the volume at 32°, and in addition to $\frac{110}{493}$ of it, that being the quantity by which it is expanded from 32° to 142°. Denoting the volume at 32° by V there is the equation

$$155 = V + V\,\frac{110}{493} \text{ or } V = \frac{493 \times 155}{493 + 110} = 129{\cdot}5.$$

129·5 cubic inches are therefore the volume at 32°. If we wish to ascertain what the volume of a gas at a low temperature should be at 32°, we adopt the same plan, but adding instead of subtracting the amount of expansion to the original volume.

When air is heated its volume is increased and ascends with a velocity proportioned to its specific lightness compared to cold air: it is owing to this principle that heavy dark smoke ascends through chimneys, and that a current of heated air is felt over every burning candle, and that in crowded theatres and such places, the upper space is found to be much warmer than the lower. The ascent of heated air causes the draught in fire-places, which supplies the fresh air necessary for combustion. The rapidity of combustion is proportioned to the supply of air, and as this supply may be regulated by promoting or retarding the ascent of the heated air, the construction and management of flues furnish us with means of regulating the intensity of fires. The Mongolfier, or fire balloon, is nothing more than a bag of air rarefied by heat.

EXPANSION OF LIQUIDS.

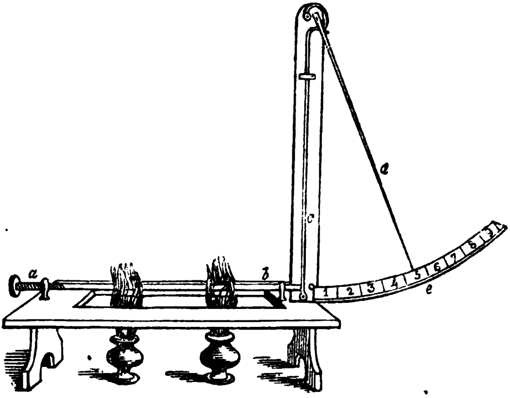
Each liquid has an expansibility proper to itself, unlike gases to which one rule applies, and the rate of expansion differs with the degrees of temperature, being greater in the higher portions of the scale. The expansibility of fluids is greater than that of solids, and less than that of gases. The following list affords an instance of the different expansion of various fluids in passing through 180° of Fahrenheit's thermometer.

Alcohol expands	$\frac{1}{9}$	Oil of turpentine	$\frac{1}{14}$
Nitric acid „	$\frac{1}{9}$	Sulphuric acid	$\frac{1}{17}$
Fixed oils „	$\frac{1}{12}$	Water „	$\frac{1}{25}$
Sulphuric ether	$\frac{1}{14}$	Mercury „	$\frac{1}{55}$

By a reduction of temperature liquids will be made to contract, and many liquids possess the property of contracting only to a certain point, below which they expand if the cooling be continued. The point of extreme contraction is called the point of maximum density. This property was at one time supposed to be peculiar to water. Other fluids, however, are found to possess it. But though these fluids possess it in a more remarkable degree, the phenomenon is of most importance in water from the beneficial nature of the results. Experiment has decided the maximum density of water to be at 39° of Fahrenheit. Water below that temperature if heated contracts, and expands if heated above it; when cooled from above it, it contracts; when cooled below it, it expands; thus the specific gravity of water at 46°, and at 32° is the same. By this property of water the solidification of lakes and rivers is prevented; for when the water at the surface is cooled below 39·8° F., it expands, and being specifically lighter than the water below it, floats on the top, thus serving as a screen to the mass which it covers, and, being a bad conductor, preventing the loss of that heat which is necessary to preserve the vast amount of life subsisting in the waters underneath. The fact so familiarly known, that ice will float upon the surface of water is accounted for by this principle, and it serves to this end. If it were otherwise, the inconvenience that must result is obvious, and would be irremediable, owing to the bad conducting power of water; it being so bad, that the very existence of such a power has been doubted.

EXPANSION OF SOLIDS.

The expansion of solids is less than that of liquids, and in like manner is not uniform. The expansion of solids, though small, is easily demonstrable by experiment. A piece of iron which, when cold, will exactly fit into a certain space, will, when heated, be too large to fit into the same space. This fact is turned to account in various ways. In shoeing carriage-wheels for instance, the iron is put on while expanded by heat, and its contraction serves at once to keep it in its proper position, and to brace the wheel. The walls of buildings which have evinced a tendency to fall away from each other, have been reduced to their original positions, by the application of this property in iron bars; and, in many instances, portions of buildings to which additional security was intended to be given by iron clamps, have been torn asunder by their repeated expansion and contraction under the successive influences of heat and cold. A variety of instruments have been invented for measuring the expansibility of different solids. Of these, it will be sufficient to describe the one represented in the accompanying cut; *a b* is the bar, the expansion of which is to be ascertained. It is fastened firmly at *a*, and at *b* rests in a groove, along which it is free to



move. This end of the bar presses against a vertical rod, *c*, which is a lever of the second order, very near the fulcrum, and this transfers its motion to the end of the lever, increased in the ratio of the distance. This lever acts on a similar one, *d*, the extremity of which serves as an index on a graduated arc, *e*, upon which the amount of expansion is read off. Thus, if the acting length of the arms of the levers are respectively 1 and 20, and that the bar *a b* moves $\frac{1}{1000}$ of an inch, the end of the index *d* will move on the scale *e* $\frac{20\times20}{1000} = \frac{4}{10}$ of an inch, a space capable of being divided by a microscope and vernier into 200 measurable spaces, so that the expansion of the two hundred-thousandth of an inch can be determined with accuracy. For popular illustration, the heat may be applied by lamps, as represented in the engraving, but for very nice calculations the bar is immersed in oil or water. The following are some of the results obtained in this way. The temperature being raised from 32° to 212°, bars of the following solids increase in length:—

Glass	varies from	$\frac{1}{1284}$ to $\frac{1}{1090}$
Copper	increases	$\frac{1}{582}$
Brass	”	$\frac{1}{532}$
Soft iron	”	$\frac{1}{815}$
Steel	”	$\frac{1}{926}$
Gold	”	$\frac{1}{661}$
Silver	”	$\frac{1}{524}$
Lead	”	$\frac{1}{351}$
Tin	”	$\frac{1}{462}$

The increase in length is called the linear dilatation; the increase in volume, the cubical, which is three times that of the linear.

SPECIFIC HEAT.

The relative amount of heat necessary to raise the temperature of any body, through a certain number of degrees, is termed its *specific heat*. If we take two pints of water, one at 50° F., the other at 150° F., and mix them in a very thin vessel, the temperature of the mixture will be 100°. Thus it is apparent, that one part of water imparted to another as much heat as was necessary to raise its temperature by 50°. If we take a pint of water at 150°, and a pint of mercury at 50°, and mix them intimately, we find the temperature of the mixture to be 118°. The mercury rises from 50° to 118°, the water cools through 32° nearly half as much, whence it appears that the same amount of heat can raise the temperature of mercury through twice as many degrees as that of water. With equal volumes the specific heats of water and mercury are as 68 : 32, or water being taken as the standard for liquids and solids, and its specific heat taken as unity, the specific heat of mercury is nearly 0·47. Such bodies are generally taken in equal weights, and not volumes, and in the case of mercury the 0·47 must be divided by 13·5, the specific gravity of mercury, and 0·035 its specific heat is obtained. This manner of determining the specific heats of bodies is called the " method of mixtures," and though liable to error from the absorption of heat by the vessel, it is capable of great accuracy, and, in the hands of Regnault, has recently yielded results of great value to science, owing to the improvements made in its details by this skilful manipulator. In using the method of mixtures, it is not necessary that the two bodies be liquid. If a pound of solid copper be heated in an oil bath to 300°, and be then immersed in a pound of water at 50°, the copper will give out its excess of heat to the water, and both will arrive at a temperature of 72°. The copper has lost 228°, and the water has gained 22°. The specific heat of copper is, therefore, $\frac{22}{228} = 0{\cdot}096$, water being 1·000. One plan adopted by Dulong and Petit, for ascertaining specific heats, was to heat to the same degree the bodies to be tried, and then allow them to cool under the same circumstances. Now, it is evident we can calculate how much heat a body parts with, if we know its rate of cooling, or the time it takes to cool. Thus, if we have two bodies at a temperature of 300°, and that one requires 15 minutes to cool to 50°, and the other 25 minutes, the latter will have parted with more heat in the ratio of 25 to 15. The substances possessing high specific heats require more time to heat or cool than those having low specific heats. By a process analogous to this, Boerhaave first discovered the relative specific heats of bodies. Having observed that, when two thin glass vessels, one containing a pound of water, the other a pound of mercury, were placed before a fire, the temperature of the mercury rose much more rapidly than that of the water, and that it attained its highest degree in one-half of the time required by the water; and, also, when both equally heated were removed from the fire, the mercury cooled twice as fast.

The specific heats of bodies are not the same at all temperatures, they increase with the temperature, and, according to Nauman and Regnault, this rule applies to water also.

When chemical combination takes place, a diminution of specific heat attends it, and by this means is caused the rise of temperature which generally accompanies chemical combination; as for instance, when sulphuric acid and water are mixed, in which case a temperature higher than that of boiling water is produced.

Considerable attention has been given to the specific heat of gases by many philosophers: the most successful of these is Dr. Apjohn of Dublin. The results of their investigations, however, are not of a nature so certain or important as to require an examination here. When the volume of a gas or of a vapour increases, its specific heat increases, and vice versâ. Considerable heat is evolved by the sudden condensation of air, and when air suddenly expands, so great a degree of cold is produced that water may be frozen.

LIQUEFACTION.

The melting point of any solid is an important characteristic, and often serves to distinguish bodies, having similar qualities in other respects. The change from the solid to the liquid state is accompanied by a peculiar phenomenon. At the moment of liquefaction a large amount of heat disappears, and cannot be recognised by the most delicate thermometer. This is called *latent heat.* A pound of ice at 32°, and a pound of water at 32°, have the same effect on the thermometer; but the water contains a quantity of heat in excess over that which ice contains, and by losing which heat it would be converted into ice. If we add a pound of ice at 32° to a pound of water at 172°, the temperature, when the ice is melted, will be reduced to 32°. In this case 140 degrees of heat have disappeared. This heat has been absorbed by the ice in becoming water, and it is, therefore, assumed that the latent heat of liquid water is 140°. A vessel of water at 52°, if exposed to air below the freezing point, will cool until it arrives at 32°, when it begins to freeze; and until it is reduced to a mass of solid ice, no sensible loss of heat occurs, though it must still be giving out heat as when it was cooling from 52° to 32°; this heat being required to give it the liquid form. If the water had taken ten minutes to cool from 52° to 32°, it will require an hour and ten minutes to be frozen, and in the same time it loses the same amount of heat, the air around it remaining equally cold, the latent heat is $20° \times 7 = 140°$, as in the other experiment. Again, if a pound of ice and a pound of water, both at 32°, be exposed to the same heat, the water will have attained a temperature of 172° by the time the ice has melted.

Water, of all liquids, contains the greatest amount of latent heat, and changes from the liquid to the solid state most slowly, and ice, of all solids, requires most heat to liquefy. By this slow transition, in both cases the changes of seasons are made less sudden than they otherwise would be. If water passed from 32° to 31°, and became solid, by losing only the same amount of heat as it gives out in cooling from 33° to 32°, the changes of seasons would be so rapid and uncertain as to frustrate all agricultural purposes, and from sudden vicissitudes of heat and cold, become very injurious to animal life. But, in the actual state of the matter, each particle of water in freezing gives out heat to all around, and thus mitigates the intensity of the cold. The quantity of water frozen is comparatively small, and where a sudden liquefaction would prove injurious to organic existence generally, the ice and snow in returning to a fluid state absorb all excess of heat, and thus render the change gradual. Water and most substances which crystallize with facility generally expand in becoming solid. Water can exert a tremendous force in this way; for, if enclosed in the strongest vessels, it will burst them by the expansion it exerts whilst freezing. To this force we owe the formation of soils from the detrition of rocks. Water finding its way into the pores, chinks, and cavities of rocks, will there become frozen, and separate the particles of the rocks. This process going on successively generates the soft and porous soil suited to the germination of seeds and growth of plants. It is by this expansive property of certain bodies that we are enabled to take casts from the moulds into which these bodies are poured in a state of fluidity. By virtue of this property, cast iron, antimony, the alloy of antimony from which printers' type is made, the alloy used for stereotype plates, brass, bronze, &c., take accurate impressions of the surfaces they are placed in contact with while in a fluid state; gold, silver, and copper, on the contrary, do not distinctly crystallize, and the impressions made upon them are the result of external force, as in coining.

The freezing point of water may be lowered considerably by the addition of salts or vegetable acids. When any mixture of this kind is reduced to the freezing point pure ice or crystallized water is first formed; for instance the icebergs of the Polar seas are almost completely formed of fresh water. This principle has been practically applied in concentrating lemon-juice and vinegar, the water of the diluted acid being converted into ice upon the sides of the vessel, the central part is filled with the concentrated acid: upon the principle of latent heat artificial cold is produced; for when a solid body becomes fluid without the application of heat, the heat required for liquefaction must be derived from the surrounding bodies, the temperature of which, along with that of the body liquefied, is reduced. Thus, when salts are dissolved in water without chemical combination cold is produced; by a mixture of nitrate of ammonia with an equal weight of water the thermometer will sink through 46°; carbonate of soda mixed with thrice its weight of water will reduce the temperature 16°; and sulphate of soda mixed with thrice its weight of water will reduce the temperature 12°. More powerful effects are produced by mixing two salts, where, by double decomposition, those soluble substances may be formed; thus, nitre and sal ammoniac form nitrate of ammonia, and cause a reduction of 40° in temperature, which neither could do separately. When water of crystallization is set free, and suddenly liquefies, cold is produced; thus, when sulphate of soda in crystals is mixed with muriatic acid, bi-sulphate of soda and chloride of sodium are formed, with which only $\frac{1}{5}$ of the water of crystallization remains; the other $\frac{4}{5}$ being set free, take from the surrounding bodies the heat necessary for their liquefaction, producing a depression of temperature through 50°.

Still greater cold may be produced by the use of pounded ice or snow. The greatest cold produced is when a substance is used which contains a large quantity of water in combination with it. Crystallized chloride of calcium, for instance, holds half its weight of water in combination, and when mixed with an equal weight of snow, the whole becomes liquid, and the heat rendered latent is large in proportion. By the combination of freezing mixtures, intense cold may be produced, a depression of temperature so low as —91° F. having been obtained in this way.

There are many instances of heat being evolved from solid bodies, of which we cannot positively state the source, though we may regard it as having been latent, as when heat is produced from the friction of two pieces of wood against each other. The most feasible way of accounting for the heat thus developed, is to assume, that as the specific heat of bodies becomes less as they become more dense, so by the compression resulting from friction heat is rendered sensible.

VAPORIZATION.

Most fusible bodies are converted into vapour by the application of a higher degree of heat than is required for fluidity. This transition may take place either slowly and silently, or with rapidity and violence, that is to say, by evaporation or by boiling. Evaporation may take place at any temperature, but boiling can take place only at certain temperatures depending upon the nature of the body and the pressure existing over its surface. When a liquid is converted into vapour, heat is rendered latent even to a greater degree than when a solid is converted into a liquid. Suppose the temperature of a cup of water to be 62°, and that at the end of six minutes it began to boil, having risen to 212°, in each minute there entered the water a quantity of heat sufficient to raise its temperature 25°. It will require the application of the same heat during 40 minutes to boil away all the water, and as in each minute there enters heat enough to raise the temperature of the same weight of water 25°, the entire amount of heat absorbed by the water, in being converted into vapour, would have raised its temperature, had it remained liquid, $25° \times 40° = 1000°$, or to a red heat. But the temperature of the vapour or steam so formed remains 212°, and all this heat is therefore rendered latent. This fact is turned to account in warming apartments by conducting steam through a series of pipes. The steam is condensed as it is brought into contact with cooling surfaces, thus giving out its latent heat, and returns in a fluid state to the boiler to be again converted into vapour. In the conversion of liquid into vapour, the volume is increased to a great degree. The amount of increase in a few cases is furnished in the following table.

	Spec. grav. water=1000.	Boiling point.	Volume of vapour at boiling point.	Vol. at 212°.	Spec. grav. vapour.
Water	1000	212°	1696	1696	620
Alcohol	907	172°	488	519	1601
Ether	715	97°	240	289	2583
Oil of Turpentine	867	315°	221	192	4763
Mercury	13,500	660°	3395	1938	6969

Vaporization occurs at all temperatures: the coldest water is capable of forming vapour; even ice will evaporate without previously being melted, and snow will disappear when the air is below the melting point and the influence of the sun's rays shut out. Camphor evaporates without melting, and arsenic is converted from a solid to a vapour without intermediate fluidity. That which is termed the elasticity of a vapour, is the pressure it exercises, owing to the mutual repulsion of its particles.

The phenomenon of boiling arises from the fact, that the elasticity of the vapour balances the pressure of the air whilst the bubble is passing through the fluid. If the pressure of the air be equal to more than that of 30 inches of mercury, water will not boil at 212°, as the elasticity of the steam formed does not balance the pressure. Before the actual process of boiling occurs, the water in contact with the vessel is converted into steam and forms a number of bubbles. When these are separated from the hot surface of the vessel, they are immediately burst by the greater external pressure, and thus throwing the water into very rapid and uniform vibrations, produce a musical effect: to this is attributable the singing of a kettle on the fire.

The elasticity of vapour increases with the temperature. The vapour of water which exercises a pressure at 212° equal to 1 atmosphere, at 398° exerts a pressure equivalent to 16 atmospheres, each atmosphere being equal to a column of mercury 30 inches high. This increase of the elasticity of steam does not result from the expansion of steam already formed, but from the constant addition of new portions of steam, which by itself expands in the same ratio with air and other gases.

The principle of volatilization at all ordinary temperatures applies to bodies very sparingly volatile. The space above the mercury in barometers is not a true vacuum, as it contains vapour of mercury, which exerts a certain pressure, making the pressure of the external air appear less than it actually is. The boiling points of fluids vary with the pressure upon their surfaces. If the barometer stood at 23·64, water would boil at 200°, less by 12 than its ordinary boiling point. The connexion between pressure and the boiling point is so intimate, that the height of any place above the level of the sea may be ascertained by the temperature at which water boils there. On the summit of Mont Blanc, water boils at 184°.

By reducing the amount of pressure the boiling point of any fluid may be lowered. In the exhausted receiver of an air-pump, fluids may be made to boil 145° below their ordinary boiling points. Under these circumstances water will boil at 67°, alcohol at 32°, and ether at the freezing point of mercury. When a fluid is boiling under these conditions, if the working of the air-pump be suddenly stopped, the vapour will accumulate, and thus by its pressure make the ebullition to cease.

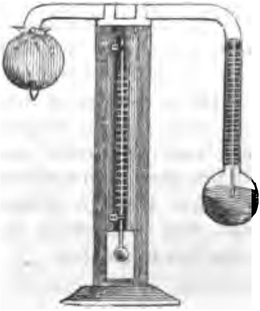
This principle may be illustrated by a familiar experiment: take a flask half filled with water, and make the water boil till all the air is expelled; then cork it tightly, invert the flask, and the part uppermost will be filled with vapour, the pressure of which upon the surface of the water prevents its ebullition; let a jet of cold water play upon that part of the flask occupied by the steam; the condensation of the vapour removes the pressure, and the water boils afresh: if a jet of warm water be then employed, the vapour retains its elastic shape, and, exerting its usual pressure, the water is made to cease boiling.

Other circumstances also will affect the boiling point. In a glass vessel, or in a glazed porcelain vessel, water boils at 214°. Metallic vessels appear to promote ebullition by the small irregularities upon their surfaces, affording the steam points at which to form. If the surface of glass be scratched with a diamond the bubbles of steam will be seen to form at the roughened part, before the general mass of the water boils. The temperature of steam is not affected by the boiling point of the water producing it; for though the boiling point of water may be raised to 264°, by the addition of certain salts, the temperature of the steam will be 212°.

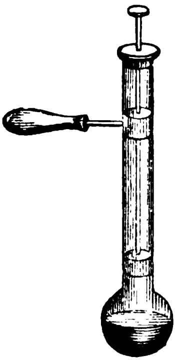
Intense cold may be produced at ordinary temperatures by the conversion of liquids into vapour; the cold which is felt when ether or spirits of wine is dropped on the skin is referable to this cause. Pour some ether into a thin, shallow metallic cup, and place it on a glass vessel containing water, by producing the rapid evaporation of the ether in the receiver of an air-pump, the water may be frozen. Water may be frozen by its own evaporation: the Cryophorus, an instrument made to exhibit this fact, consists of a tube with a bulb at each end, containing some water; the air is carefully expelled by boiling, before the instrument is closed, so that the space not occupied by water is filled by watery vapour. If all the water be brought into one bulb, and the other bulb be plunged into a freezing mixture, this vapour will condense, and, new vapour being formed, a distillation will take place from one end to the other. The vapour thus formed must derive its latent heat from the water in the warmer bulb, which ultimately freezes; the latent heat of watery vapour at 32° being about eight times the amount of that of water. Even without the application of cold, water may be frozen by its own evaporation. If we place two flat dishes under the receiver of an air-pump, the upper one containing water, the lower oil of vitriol, and having removed the air, leave the apparatus for a short time to act, we find the water frozen, the vapour having been absorbed, as fast as it was generated by the sulphuric acid, which has a powerful affinity for water. In more volatile fluids this simultaneous freezing and evaporation is still more remarkable. If a glass rod be dipped in prussic acid, part of the drop which is pendent from the end of the rod will be frozen by the evaporation of another portion of it. The singular phenomenon of the solidification of carbonic acid arises from the same principle. A jet of fluid carbonic acid being allowed to escape, one part instantly becomes gas, and absorbs so much heat, that the portion which remains is converted into a compact mass. In warm climates, the temperature of the air is moderated by the evaporation of water. The Spaniards use earthen vessels called *alcarrazas*, of a porous nature, through which any liquid placed within will filter, and the evaporation on the outside will preserve the contents cool.

When the air is not quite saturated with watery vapour it is difficult to determine the exact amount it contains: one of the best methods consists in cooling the air until its volume is so much diminished that the quantity of vapour is sufficient to saturate it, and from the temperature at which this occurs the amount of vapour may be calculated. This temperature is called the dew point, for, if cooled below this point, a quantity of water is deposited in the form of dew upon the surrounding cold bodies. Taking a large glass full of water and cooling it, by dissolving gradually in it a little mixed nitre and sal-ammoniac, until a deposition of dew is perceptible on the outside of the glass, water is brought to the temperature of the dew point. Another method of determining the quantity of vapour which air contains, is by observing the rapidity of evaporation from the surface of the bulb of a thermometer which is covered by muslin kept wet with water. The thermometer in this condition is always at a lower temperature than an ordinary thermometer, from the quantity of heat carried off by evaporation, and the temperature becomes lower in proportion to the evaporation. In dry air evaporation is most rapid; in air saturated with moisture it ceases; and in every intermediate degree there is a connexion between the quantity of moisture already present in the air and the depression of temperature which accompanies the formation of as much more as will saturate it. This method has a peculiar interest from the means afforded by it to Dr. Apjohn of ascertaining the specific heats of the gases.

The quantity of watery vapour existing in the atmosphere is ascertained by instruments termed hygrometers, of which that of Professor Daniell is the most generally approved. This is a cryophorus, containing ether, having in one bulb a very delicate thermometer; this bulb is made of blackened glass, and the other bulb is covered with a muslin bag; all the ether having been made to pass into the black glass bulb, a little ether is poured on the envelope of the other bulb. This, by condensing the vapour within, causes the ether to pass in vapour from the blackened bulb, and in



this manner cools it and the air in contact with it, until it arrives at the point of saturation, when a watery dew begins to be deposited, which is at once observed upon the blackened glass. The internal thermometer indicates the temperature of the bulb, which is the dew point, and a thermometer which is attached to the support of the instrument gives the temperature of the air.



A few words in relation to the principle upon which steam is applied, as a moving power, will not be considered inappropriate here. The small cylinder of Wollaston, represented in the engraving, embodies all that is essential to the production of motion, by the application of steam. This philosophical toy consists of a glass tube, terminating below in a bulb. It is fitted with a steam-tight piston, the rod of which passes through a brass cap at the top. If a little water be placed in the bulb and boiled, the steam pressing upon the bottom of the piston forces it up: if the bulb be then dipped in cold water the steam will be condensed, and the pressure of the external air on the top of the piston forces it down again. This process may be repeated at will, and constitutes the essential principle of the atmospheric steam-engine of Newcomen. This was the simple machine upon which Watt brought to bear the powers of his high intellect; and, applying the discoveries of the properties of heat made by himself and Dr. Black converted it, without altering its fundmental principle from the rejected and all but useless one of Newcomen, into that engine which, though not yet fully developed, has wrought greater changes, social and physical, than any other, with one exception, which the genius of man has originated.

TRANSMISSION OF HEAT.

THAT heat is conducted through different bodies with different degress of facility, is a fact familiarly known. If one end of a poker be heated to redness, the other end will become inconveniently hot to hold in the hand, whilst a stick of the same length may be burning at one end without raising the temperature of the other end to any remarkable extent. Bodies through which heat passes rapidly are termed conductors; bodies like wood and glass, which obstruct its passage, are called non-conductors; but the difference is only in degree, as no body is a complete non-conductor. Many experiments have been made, and are in popular use, which demonstrate the relative conducting powers of bodies, but into a description of these it is not our purpose to enter here. The following conducting powers are deduced from experiments made by Despretz, gold being taken as the standard for comparison:

Gold	1000	Tin	304
Silver	973	Lead	180
Copper	898	Marble	23·6
Platinum	381	Porcelain	12·2
Iron	374	Fire clay	11·4
Zinc	363		

The principle of the difference of conducting power in solids is in constant application in ordinary life. The conducting power of fluids is very low; it was thought that no power to conduct heat existed in them, and that they were true non-conductors. It has been proved, however, that they do conduct, and the power appears to be in the ratio to their density, mercury being the best conductor, alcohol and ether the worst.

The communication of heat through large quantities of fluid is effected by diffusion, not by conduction, and the source of heat must be underneath. When the lower portion of the fluid is heated it expands, and becoming specifically lighter it ascends, and is replaced by the upper and heavier, which is heated in turn, and this is repeated till the whole mass is uniformly heated. In the mode of conducting heat gases resemble fluids, the true conducting power being scarcely appreciable; but, by the currents formed by the ascent and descent of warm and cold particles, they abstract and conduct heat rapidly. The non-conducting power of gases is of great practical utility. The different kinds of clothing in use owe their warmth to their power of preventing the escape of heat from the body; this is effected not by the solidity or compactness of their structure, but being of a loose and spongy texture, they confine in their pores a quantity of air, which, being unable to form currents, acts as a non-conductor. The tissue of a cloth confines more air, and is therefore the warmer, the more loose and spongy its texture may be. This fact is confirmed by the experiments of Count Rumford, who, having heated to the same degree a thermometer wrapped up in the usual materials from which clothing is manufactured, found that it cooled through 135°, with

Air	in 576″	Raw silk	in 1284″
Fine lint	„ 1032″	Beaver's fur	„ 1296″
Cotton wool	„ 1046″	Eider down	„ 1305″
Sheep's wool	„ 1118″	Hare's fur	„ 1315″

The power of retaining warmth is lessened in proportion to the degree of compression to which these bodies may be submitted.

RADIATION.

Every hot body has the property of emitting heat in straight lines from all points of its surface; this is called radiation of heat. Thus, when we stand before a fire we feel its heat, though a current of cold air is continually flowing in the direction of the fire; and an iron ball suspended in a room diffuses heat upon this principle in all directions. Radiation differs from conduction and diffusion in not requiring any material medium for its conveyance; on the contrary, it is obstructed by the interposition of any body; and in most solids and liquids there is little heat transmitted by radiation, unless conduction be regarded as a radiation from particle to particle. A heated body throws off rays of heat in the same manner as a luminous body throws off rays of light: in the radiant forms a perfect similarity exists between the two. The radiating power of bodies appears to depend more upon the mechanical nature of their surfaces than upon any internal peculiarity of structure. When any substance is placed in the path of the rays of heat, these are either reflected or absorbed, or pass through the substance without suffering any loss, all these effects are in part produced; that is, one portion of the rays will be reflected, another transmitted, and a third will be absorbed. Substances in relation to heat are said to possess four powers,—the radiating, the reflecting, the absorbing, and the transmitting. The rays of heat, like the rays of light, may be concentrated by reflection, or by refraction. The properties of radiant heat may be easily demonstrated by the mode originally adopted by Leslie and Prevost. The apparatus in popular use for demonstrating the properties of radiant heat consists of mirrors of polished plated copper of the parabolic form. By a property of this form of reflector the rays emanating from the focus of one mirror are reflected from it in parallel lines, and, thus falling upon the other reflector, are converged in its focus. By these means, heat radiating from a body may be concentrated upon a single point. Thus, a hot iron ball may be placed within a few feet of a bit of phosphorus without affecting it; but if the hot ball be placed in the focus of one mirror and the phosphorus in the focus of the other, the effects of the heat are at once seen by the phosphorus bursting into flame. If the hand be held in the focus it feels hot; if moved nearer to the source of heat (the iron ball) it feels cool. Leslie, by experiment, determined the relative radiating powers of the following substances:—

Lamp-black .	100	Plumbago .	74
Writing-paper	98	Tarnished lead .	45
Crown-glass .	90	Clean lead .	19
Ice . .	85	Polished iron .	15
Red lead .	80	Other bright metals	12

The radiating power, it will be seen, is independent of the colour of the body; and that those bodies radiate least which have bright metallic surfaces. Recent investigation, however, has rendered it probable that the radiating power has not so much relation to the polish of the surface as to its density: the surface of a metallic plate is greatly compressed in the process of polishing, especially if it be rolled, and in this state radiates in the lowest degree; but if the dense film of compressed metal be removed by rubbing with sand-paper, the softer metal underneath radiates with double the power. If a plate of silver be cast without being subjected to any pressure, the surface, though perfectly bright, radiates with a power of 22°, but if it be dimmed by being rubbed with sand-paper, the compression, slight as it must have been, diminishes the radiating power to 12°. The radiating power of bodies may be consulted with profit in the most familiar operations: thus, a painted tin vessel filled with warm water will cool more rapidly than a polished one under similar circumstances, owing to its greater radiating power, as the bodies which radiate least cool slowest; and, if placed before a fire, the painted tin vessel will absorb heat more rapidly than the polished one. Colour, though having no influence over the radiating power, influences the absorbing power in a remarkable degree. If pieces of cloth of various colours be laid upon snow, exposed to the direct rays of the sun, black cloth will, by absorbing most heat, melt the snow under it and sink deepest, white will sink least, and the intermediate colours in the order of their depth of hue; a proper regard is paid to this fact in the selection of dark-coloured cloths for winter clothing, and in the preference of those of lighter colours for summer wear, though the philosophy of the fact is not, perhaps, so generally known. It is upon the absorption of those rays of heat which accompany rays of light only, that this property of colour depends. Bodies possess the property of reflecting in an inverse ratio to their absorbing and radiating powers, and hence those which absorb best reflect least. The heat of the sun's rays may be concentrated in the focus of a burning mirror to such a degree, that results equal to those produced by the most intense artificial heat may be had. As the rays of heat accompany those of light in their passage through lenses, concentration by refraction may also be effected; hence the property of the burning-glass, or lens. One of these instruments, of great size and power, is now being publicly exhibited in London, at the "Adelaide Gallery of Practical Science."

The cooling of bodies by radiation is regulated by the principle, that all bodies are in a continual state of interchange of heat,—hot bodies radiating, and colder bodies absorbing the heat so radiated. Every body in nature, therefore, by mutual radiation and absorption tends to produce an equilibrium of temperature. This fact explains a singular experiment with the parabolic reflectors before spoken of. If instead of the heated iron ball we place in the focus of one mirror a mass of ice, the temperature of the thermometer in the focus of the opposite mirror will sink below that of the surrounding air; the thermometer having more heat than the ice, radiates more than the ice can return to it, and therefore has its temperature lowered. This effect was at first attributed to the radiation of rays of cold which were supposed to exist. The formation of dew and frost is attributable to this principle of the uniformity of temperature being sustained by radiation and absorption. During the absence of the sun, the surface of the earth loses by radiation a great amount of heat, and if it were not for the radiation in return of the clouds which are generally over the earth, its temperature would be considerably reduced. If the clouds be absent, the heat radiated by the earth is all lost in the planetary spaces, and the temperature of the earth is much lowered. The air which is in contact with the earth's surface is then cooled, and the watery vapour which it held in its more elastic form, is deposited in the shape of dew. If the air itself be at a low temperature, and the night a very clear one, the drops of dew as they are deposited congeal, and thus frost is produced. The accuracy of this statement is proved by the fact, that it is only on the surfaces of good radiators and in clear star-light nights that dew or frost is formed. If a plate of polished metal be placed upon a rough board and exposed to the air of a frosty night, no trace of frost will be found upon the metal, but the rough surfaces of the board will be covered with frost. Ice may be obtained between the tropics by an application of this principle; for instance, if a thin layer of water be lightly covered with straw to increase the radiating power it will be found frozen in the morning, though the temperature of the air during the night may have continued far above the freezing point. If we interpose a screen of any substance which will prevent the passage of radiant heat, the deposition of dew or frost will cease at once, which proves that the cold produced is by radiation of heat and not by contact or diffusion of the particles of the air. Thus plants are protected by mats from the effects of frost, and thus vegetation is favoured by a coat of snow preventing the radiation of heat from the soil beneath.

Heat is derivable from many sources. To our planet the sun is the principal source of warmth, and to the influence of the sun's rays, modified by our varying position in relation to the sun by which these rays are made to fall upon the earth at different inclinations and to pass through media of different densities, are owing the changes of the seasons and the various phenomena of organic and inorganic nature consequent upon them. But the earth has within itself a source of heat, which at one time was sufficient to retain in a state of igneous fusion the entire mass of mineral constituents which form so large a portion of it. By perforating the earth to a depth of about forty feet, we arrive at a layer of which the temperature is the same, in winter and summer. This is called the stratum of invariable temperature, and is generally of the mean temperature of the place, that is to say, the temperature of the surface in winter falls as much below that of the invariable stratum as in summer it is raised above it. The heat of the sun's rays falling upon the surface, is transmitted inwards by the conducting power of the earth: in this manner a layer of elevated temperature moves inwards every summer, each layer having one of lower temperature interposed, marking the period of winter cold, until both arrive at the stratum of invariable temperature, below which the sun's influence does not extend. On perforating beyond forty feet the temperature is found steadily to increase, at a rate generally of about one degree for every forty-two feet, or about 120° for a mile. At a depth of two miles, therefore, water could exist in a liquid state only by virtue of the great pressure exerted on it by the superincumbent earth; at four miles' depth, tin and bismuth should be liquid; at a depth of five miles lead should be found in a state of fusion, and at 30 miles' depth the heat should be sufficient to fuse iron. There is every reason to believe that a central heat of great intensity is in active existence, though its effects are unfelt at the surface of the earth. The solid crystalline shell which has formed over the melted mass, and which constitutes the crust of the earth, extends to only $\frac{1}{140}$ of the distance to the centre. The existence of an orifice or fissure in this crust may easily be supposed to occasion the phenomena of earthquakes and volcanoes.

Chemical combination is a general source of artificial heat. Percussion, friction, the respiration of certain kinds of animals, and electricity, are also sources of heat.

ELECTRICITY.

AMBER was the first substance in which the electrical property was discovered, and its Greek name, *ηλεκτρον*, gives the etymology of the word electricity. Nothing is positively known of the true nature of electricity. It cannot be determined whether it is a mere property of matter, or a force acting independent of all material connexion, or whether, like light, it consists of undulations of an ethereal medium. The common views taken of its nature are embraced in the supposition of the existence of one or of two fluids, perfectly elastic and of extreme tenuity; and that bodies acquire or lose the properties conferred by electrical excitation in proportion to the amount of these fluids they may contain. No evidence has ever been obtained of the existence of such fluids; it has never been possible to separate electricity from the particles of matter of which it appears as a property assumed under peculiar conditions, and not as a constituent. The word fluid, however, in connexion with electricity is generally adopted for convenience; but its use does not imply a belief in the actual physical existence in that form of the power in question.

Friction is the operation in general use for the development of electricity. If we take a dry silk handkerchief and rub it briskly against a dry glass rod, a peculiar odour will become perceptible; if the friction be made in the dark a peculiar light will be evident; and if any light bodies, as bits of paper, balls of elder pith, or a silk thread, be placed near the rod, they will be attracted to it, and will adhere to it, but after a short interval will be repelled. The glass rod, in this case, is said to be electrically excited; the luminous appearance is called electrical light, and the motion of light bodies to and from the glass rod is termed electrical attraction and repulsion. These phenomena may be produced by the friction of other bodies than silk and glass. Two pieces of silk, especially if they be of different colours, become excited by being rubbed against each other: thus by laying together slips of black and of white ribbon, and drawing them quickly through the fingers, each will attract light bodies and each the other. A piece of sealing-wax, or of any other resinous composition will become excited by friction with flannel or woollen cloth. Sulphur and amber assume this state with remarkable facility and power. This excitability is not common to every body. Even the bodies mentioned, in certain conditions, cannot be excited: thus, if the silk, or flannel, or glass rod, be damp, no electric properties can be induced. A metallic surface resting upon the ground, or supported by the hand, cannot be excited by any amount of friction. Such a body is termed a *non-electric.* Dry glass, resin, sulphur, silk, amber, &c., are called *electrics.* This distinction, however, is not complete; for if the metallic surface be supported by a glass or resinous handle, it becomes as capable of excitation by friction as any of the electrics. Electricity being highly elastic, its particles repel each other, and tend to escape from the surface upon which they are accumulated. Certain bodies are supposed to possess the power of retaining the electric fluid on their surfaces in a greater degree than others, and thus produce the phenomena of electrical excitation; they are electrics, therefore, because they are *non-conductors.* But the metals, &c., are not so constituted as to retain the electric fluid on their surfaces, unless its passage be prevented by the interposition of a non-conductor, and are, therefore, non-electrics, because they are conductors; and where a non-electric is made to retain the electric fluid on its surface by being supported upon a non-conductor, it is said to be *insulated*. Perfect dryness is as necessary for insulation as for the production of electricity by friction; for, if the slightest film of moisture be present, it will serve as a conductor, and the electricity will escape. The following is a list of the best insulators, or worst conductors, set down in the order of their insulating powers respectively:

Dry air.
Shellac.
Resins.
Oil of turpentine.
Sulphur.
Glass.
Spermaceti.
Damp organic bodies.
Damp air.
Water.
Strong acids.
Fused saline bodies.
Charcoal.
Metals.

The worst metallic conductor is many thousand times a better conductor than water. It is known that a wire along which an electric charge is passed becomes heated in proportion to the resistance offered to the motion of the fluid; the rise of temperature is, therefore, in an inverse proportion to the conducting power. From experiments conducted on this principle, Mr. Snow Harris deduced approximations to the conducting powers of the following metals:

	Heat evolved.	Conducting power.
Silver	6	120
Copper	6	120
Gold	9	80
Zinc	18	40
Platinum	30	24
Iron	30	24
Tin	36	20
Lead	72	12

Professor Wheatstone has given much attention to the examination of the velocity with which the electric impulse is conducted. By means which cannot be detailed here, he has been enabled to determine an interval of the

$\frac{1}{152000}$ of a second; he found that the impulse of the shock of a Leyden jar is transmitted from each end of an interposed wire, and arrives latest at the centre, and that the velocity with which this impulse is transmitted is greater than that of the passage of light through the planetary spaces, namely, at the rate of more than 195,000 miles in a second.

Electricity when evolved accumulates upon the surface of a body, and by its electric property tends to break away and pass to bodies unexcited. This passage through air produces the electric spark and the snapping report which accompanies it. The manner in which electricity is distributed on the surface of bodies is considerably influenced by the form of the body; the layer is of equal thickness on a sphere, on an elongated body it accumulates at the extremities of the longest axis. Thus, on a wire, it is almost entirely accumulated at the ends, and electrical machines are constructed smooth, save where points are attached for the escape of the electric fluid.

We have seen that bodies rubbed together become electrically excited, so that each body separately gives evidence of its excited condition. When these bodies, however, are brought into contact, they destroy each others' power; and bodies thus oppositely electrified attract each other, whilst bodies similarly excited repel each other—this force of attraction and repulsion diminishing in intensity like that of gravitation, as the square of the distance between the two bodies is increased.

There are two theories of electricity,—that of Dufay, which supposes the existence of two fluids; and that of Franklin, which admits the existence of one only. Dufay assumed that two kinds of electricity exist in nature, each a highly elastic fluid, whose particles repel each other according to the law of the inverse square; and, according to the same law, attract the particles of matter, and also attract each other; that every body contains usually an exactly equal quantity of each fluid, and in this case is in an ordinary state, and accordingly quiescent; but if a body contain more of one fluid than of another, it is in an extraordinary state, and, acquiring new properties, is said to be excited. Thus, according to this theory, when two bodies are rubbed together, one fluid accumulates in excess upon the one, and the other kind of fluid upon the other body. They are thus both excited; and as the excess of the one fluid must be exactly equal to that of the other, the excitation of both is equal; but, being opposite, they will neutralize each other when brought together. The electricity which passes to glass when rubbed, is styled by Dufay vitreous electricity; that which accumulates on resin when rubbed with flannel, he called resinous; but those names have fallen into desuetude, from the fact that there are few bodies which are not capable of assuming vitreous or resinous excitation, according to the substance with which they are rubbed.

Franklin assumed the existence of only one electric fluid, of which he supposed every body in its ordinary state to contain a certain quantity. This fluid he considered to be highly elastic; to be capable of repelling its own particles, with a force varying with the inverse square of the distance, and of attracting the particles of matter according to the same law. Any substance holding.a proper share of electricity is, therefore, in its indifferent state, and possesses no extraordinary qualities. When two such bodies are rubbed together a quantity of electricity leaves the one and accumulates upon the other; thus they are both brought into an unusual state, and assume the characters peculiar to electrical excitation. The excitation being equal, for the one has gained just as much as the other has lost, they destroy each other's action when brought together, and return to their ordinary state. In this case, one body is said to be *plus*, (+) the other, *minus*, (—), electrified; or, more frequently, one is said to be *positively*, the other *negatively* excited, and the + and — are often used for these words. Considerable advance has been made towards a theory of electricity upon this principle. To account for the molecular constitution of matter, it is necessary to suppose that the forces which act upon its particles may change from attractive to repulsive, and again from repulsive to attractive, according as the distance between the particles is made to vary; and, according to Mosotti, "it is only necessary to assume that the mutual repulsion of matter, when destitute of electricity, is inferior to its attraction for electricity, and to the mutual repulsion of the electricity itself, and the law of gravitation becomes a necessasy consequence of the conditions under which alone electrical equilibrium can be established."

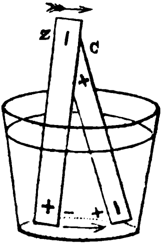
The theories just stated are those which have been most generally received. Writers usually adopt the language of the theory of Dufay, but use the words positive and negative in place of vitreous and resinous.

When it is desirable to develop electricity in a state of high intensity and power, machines are used which are specially constructed for this end. They are of two kinds; in both, a surface of glass, more or less extensive, is exposed to friction: in one case in the form of a cylinder, in the other of a plate; of the latter kind one of colossal dimensions may be seen in the Polytechnic Institution of London.

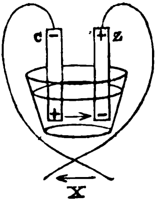
Though anything like a detailed description of the mechanical and natural sources of electricity does not properly come within the scope of this treatise, exception may be taken in favour of one particular case, where a remarkable phenomenon of frequent recurrence may be accounted for. Changes in the state of aggregation are the source of electricity of the greatest importance, because the most universal in their action. Disturbance of electrical equilibrium is occasioned when any body passes from the liquid to the solid state, or from the liquid to the vaporous, or when a solid or vapour becomes liquid. Vaporization is one of the most abundant sources of electricity; for at all ordinary temperatures evaporation takes place from the surface of the globe, and the vapour so produced taking with it the vast amount of positive electricity thus set free, mixes with the air which is continually kept in a state of high electrical excitation. The vapour when condensed by the cold of the higher regions of air, forms a cloud, in which is condensed the electricity evolved by evaporation from the earth's surface. Clouds thus intensely electrified are attracted to each other, or to some prominent object on the earth, when the discharge and neutralization of their electricities occur, accompanied by the phenomena of lightning and thunder; the latter occasioned by the reverberation of the accompanying report, from the surfaces of other clouds, or by the sides of mountains in the vicinity.

GALVANISM.

The manner in which this form of electrical excitation is developed may be demonstrated by a very simple experiment. If a slip of pure zinc be partly immersed in dilute muriatic acid, no chemical action is apparent and no electrical disturbance is created; but if a slip of copper be introduced which touches the zinc out of the fluid, decomposition of the muriatic acid actively commences, the chlorine (one of the constituents of the muriatic acid) combining with the zinc, and the hydrogen (another constituent of the acid) appearing in the form of minute bubbles on the surface of the copper. Simultaneously with this decomposition is produced a remarkable state of electrical excitation in which the zinc resembles a body to which negative electricity in a state of very low tension is supplied, whilst an equal quantity of positive electricity flows along the copper, and these uniting at the point of contact between the two metals, produce the effects known as those of the electric current, the passage of which is demonstrable in a variety of ways. In this case we may suppose, that the chemical relations of the zinc and muriatic acid are such that, when placed in contact, they mutually induce on each other a development of electricity, that part of the zinc which is immersed becoming +, and that not immersed — ; whilst the molecules of the acid near the zinc become —, and the general mass of the fluid obtains + excitation. The + electricity of the zinc being, however, balanced between the electricities of its own mass of the acid, and the — electricity of the acid being in equilibrium between the + electricities of the zinc and its own particles, "it results, that this condition of induced excitation may remain for any length of time without increasing or diminishing in intensity, the apparatus being in the condition of a very feebly charged Leyden jar; and, on applying the slip of copper by which the excited surfaces, the zinc, and acid, are placed in communication, the negative electricity of the zinc unites with the positive of the copper, by direct translation or by inductive action, and the positive electricity of the liquid unites with the negative of the copper to produce neutralization, at the same time the + of the zinc and — of the acid combine. As, according to the theory of Franklin, the single electric fluid is supposed to pass from the body which is positively to the body which is negatively excited, it is usual to imagine this exchange of electricities to take place by a current which in this case, as shown by the arrows in the annexed figure, is from the copper to the zinc at the superior junction, and from the zinc to the copper in the acid." The passage of the current is accompanied by the solution of the zinc and the liberation of the hydrogen, the latter accompanying the positively electrified molecules of the acid across the fluid, and discharging itself under the form of gas upon the surface of the copper. The requisites to produce a current



of electricity are, therefore, in the first place, two bodies, one simple and one compound, which will act chemically upon each other in such a manner as that the simple element shall supply the place of a constituent of the other which shall be expelled; and, secondly, a conducting substance which is indifferent in a chemical point of view, and merely affords a route for the electricities of the actual elements to recombine. In the example just given, this conductor was a slip of copper; it may, however, be of any form, or almost of any substance, as in the annexed figure a wire may be soldered to the end of each slip, and on bringing these wires into contact at x the current passes as if the contact of z and c had been direct. An arrangement of this kind is termed a *simple circle*. The metal which acts as a conductor remains uninjured, and so far from evincing a tendency to combine with the chlorine or oxygen of the liquid, it would separate if previously combined. On this principle a method of preserving the copper sheathing of ships was adopted. Small portions of iron of about the $\frac{1}{500}$ of the surface were attached, the chlorine of the salt in the sea-water was transferred to the iron, and the copper, in place of becoming covered with the green rust of oxychloride of copper, remained uncorroded and bright. The principle, however, was found in practice to be attended with inconvenience, for the negative elements of the sea-water being transferred to the iron the possitive, lime and magnesia were deposited upon the copper; and, offering points of adhesion for shell-fish and marine plants, caused the bottoms of the vessels to become so foul as to injure, to a considerable extent, their sailing qualities. Fixing a layer of zinc upon iron surfaces, a process in very general use, protects them from rust upon the same principle.



The electrotype process, which has obtained such an extensive popularity, is based upon the principle of this transfer of the exciting liquids. One of the liquids being a solution of sulphate of copper, the metallic copper is deposited upon the surface of the plate to which the current passes in the liquid, and forms upon it a layer of metal, which takes a precise cast of the surface upon which it is thrown.

The electricity evolved by chemical action in simple circles, is present in much greater quantity than can be developed by friction with the largest machines; but it cannot acquire the same intensity owing to its continued recombination. The immersion of two wires, one of platina, the other of zinc, each 0·06 of an inch thick, to a depth of five-eighths of an inch in dilute sulphuric acid, for three seconds, gave as much electricity as could be generated by thirty turns of the most powerful machine of the Royal Institution. And Dr. Faraday has shown that, in the current which passes during the decomposition of a grain of water, more electricity is contained than in the brightest flash of lightning.

To commence with the accidental discovery of Galvani, a professor of anatomy at Bologna, that the legs of a frog are thrown into convulsions by the contact of wires applied in a particular manner, to describe the pile of Volta with Crookshank's improvement upon it, and also the ingenious contrivances of Mullins, Daniell, and Groves, or to particularize and account for the phenomena resulting from the action of Galvanic or Voltaic electricity, would involve considerations of a nature too important, and in detail too elaborate, to be comprised in the limited space which can be devoted to them here.

CHEMICAL NOMENCLATURE.

The simple substances known at present are fifty-five in number. The names of these, with the symbols which represent them, are as follow:

Oxygen	O.
Hydrogen	H.
Nitrogen	N.
Carbon	C.
Boron	B.
Silicon	Si.
Sulphur	S.
Selenium	Se.
Phosphorus	P.
Chlorine	Cl.
Iodine	I.
Bromine	Br.
Fluorine	F.
Tellurium	T.
Mercury	Hg.
Zinc	Zn.
Cadmium	Cd.
Cobalt	Co.
Nickel	Ni.
Potassium	K.
Sodium	Na.
Lithium	Li.
Barium	Ba.
Strontium	Sr.
Calcium	Ca.
Magnesium	Mg.
Aluminum	Al.
Glucinum	G.
Zirconium	Zr.
Thorium	Th.
Yttrium	Y.
Cerum	Ce.
Lanthanum	Ln.
Manganese	Mn.
Iron	Fe.
Copper	Cu.
Titanium	Ti.
Arsenic	As.
Antimony	St.
Tungsten	W.
Molybdenum	Mo.
Tantalum	Ta.
Chromium	Cr.
Vanadium	V.
Uranium	U.
Gold	Au.
Iridium	Ir.
Osmium	Os.
Platinum	Pl.
Tin	Sn.
Lead	Pb.
Bismuth	Bi.
Silver	Ag.
Palladium	Pd.
Rhodium	R.

The various substances which exist in nature are formed by the combination of these bodies with each other. The first thirteen in the list are non-metallic elements, the rest are metallic.

Chemical nomenclature, until the time of Lavoisier and Guyton, was based upon the prevailing theories of the day; these philosophers introduced a system of names intended to denote the proper chemical characters and constituents of the bodies examined.

The words *acid, base* and *salt* are much employed in chemistry; the word *acid* is used to designate any body that imparts a sour taste: the term *base* implies any substance which in conjunction with an acid forms a compound to which the name of *salt* is generally given.

Simple bodies in combining, form, in the first instance, what are called *binary* compounds. The names of those possessing oxygen are of two kinds, according as the compound has acid properties or not. In the first case, the word acid and the termination *ic* are supplied; thus, the compound of sulphur and oxygen is sulphuric acid. If the same body form with oxygen two acids of different strengths, the stronger is known by the termination *ic*, the other by the final syllable being *ous*. Thus we have *sulphurous* acid, and *sulphuric* acid. When a substance forms with oxygen more acids than two, the words ὑπο under, and ὑπερ over, are used. Thus, we have an acid of sulphur with less oxygen than the sulphurous; this is called *hypo-sulphurous* acid: and another acid with more oxyen than the sulphurous, but with less than the sulphuric; this is termed *hypo-sulphuric* or *hyper-sulphurous* acid. When a compound formed with oxygen is not an acid, it is termed an *oxide*, as oxide of lead, oxide of iron, &c. In some cases, when oxygen unites with bodies in more than one proportion, one compound may be an acid and another not. Manganese forms with oxygen *manganic acid* and *permanganic acid*, and with less oxygen oxides of manganese.

Oxides also are formed with various proportions of oxygen, and the proportions are expressed by the words προτος first, δευτερος second, τριτος third, prefixed to the word oxide; thus, protoxide of lead, deutoxide of lead, tritoxide of iron. The oxide containing most oxygen is called a *peroxide*, that containing least a *suboxide*. The word *sesqui* (one and a-half) is used to designate oxides intermediate between protoxides and deutoxides.

Other simple elements form compounds with the metals, as

Chlorine	forming	Chlorides
Iodine	,,	Iodides
Bromine	,,	Bromides
Fluorine	,,	Fluorides.

And in like manner, but with a different termination,

Sulphur	forms	Sulphurets
Selenium	,,	Seleniurets
Tellurium	,,	Tellurets
Carbon	,,	Carburets
Nitrogen	,,	Nitrurets
Phosphorus	,,	Phosphurets
Arsenic	,,	Arseniurets.

The Greek prefixes are also used with these; thus we have *proto-chlorides* and *deuto-chlorides*; the Latin *bis* being often used for the Greek *deuto*, as *bichloride.*

The combinations of the metals with each other are termed *alloys*, except when mercury enters into combination with another metal, when the compound is called an *amalgam.*

By the union of two primary compounds, *secondary* compounds are formed. These are generally termed *salts*, but the iodides, chlorides, bromides, and fluorides, are also classed as salts.

When two oxides of the same metal form with an acid two distinct classes of salts, the words *proto, deuto, sesqui*, or *per*, which distinguish the oxides, are prefixed to the generic name of the salt; thus we say, protosulphate of iron, when protoxide of iron is the base, and persulphate of iron when the peroxide is in composition. When the acid is in excess in a salt we use the Latin words *bi*, *ter*, &c., to indicate the amount as *bisulphate.* When the base is in excess, we employ the words δις, τρις, &c., as disulphate of zinc, trisulphate of mercury.

Water enters into combination with many substances; these are called hydrates, or the substance is said to be hydrated. Oxides and chlorides form *oxy-chlorides*; oxides and sulphurets, *oxy-sulphurets*; chlorides and sulphurets, *chloro-sulphurets.*

The union of two secondary compounds will form a *ternary* compound, such as dry alum, which is a compound of sulphate of potash and sulphate of alumina. Alum in the crystallized state is a *quaternary* compound, being in combination with water.

The practice of using symbols to denote both simple and compound bodies is now universally adopted in chemical essays and lectures. The symbol of any simple element is generally the first letter of its name, and whenever the name of more than one element has the same initial, they are distinguished by adding to one, another letter in smaller type, which may be either the second letter of the word, or the one that will best serve to characterise it. To form the symbols of the compound bodies, it is only necessary to place together the symbols of the simple elements; thus, Pb.O. means a compound of lead and oxygen; C. H. N. O. a compound of carbon, hydrogen, nitrogen, and oxygen. The sign + is often used to connect symbols, as Cl. Ca. + 6 H. O. chloride of calcium in combination with six proportions of water.

Connected with symbols is the idea of proportion. With the name of every element is associated the proportion in which it combines with other elements. Thus Pb. is not regarded as the representative of lead only, but also of its chemical equivalent 103·6, and in like manner with all the rest. Pb. O. denote not an indefinite compound of lead and oxygen, but a compound of one equivalent of lead, and one equivalent of oxygen, in the proportion by weight of 103·6 of lead, and 8·0 of oxygen. Pb. O_2. signify a compound of one proportion of lead, with two proportions of oxygen.

CHEMICAL AFFINITY.

SUBSTANCES, elementary or compound, evince a disposition to combine with other substances of a different nature. This tendency to combination is controlled by a certain law, which is termed *Chemical affinity*. Thus, if we add to muriatic acid a mixture of lime and magnesia, the lime will be all dissolved in the acid before any of the magnesia will be acted upon. If we place a slip of iron in some nitric acid, deep red fumes are evolved with effervescence, and the metal is dissolved, having entered into combination with the liquid in the room of the substance driven off. A slip of copper will be similarly acted upon; but if iron and copper be placed together in the acid, the iron is all dissolved before the copper is attacked by the acid. Thus muriatic acid combines with lime in preference to magnesia, and nitric acid acts upon iron in preference to copper—chemical affinity is therefore said to be *elective;* it selects from a number of bodies that upon which its force is to be developed, and in this respect differs from the forces of gravity and of cohesion, which are exerted upon all bodies exposed to their influence, at the same time.

Chemical force produces another phenomenon, namely, *decomposition.* Thus before iron enters into combination with nitric acid an element is expelled. The following is a good example of decomposition resulting from the exercise of chemical affinities. If sulphuretted hydrogen, which consists of sulphur and hydrogen, be brought into contact with iodine, the iodine combines with the hydrogen, expelling the sulphur; that is to say, the sulphuret of hydrogen is decomposed, and iodide of hydrogen is formed. In this case the hydrogen exercised an elective force by entering into combination with the iodine in preference to the sulphur, and decomposition was the result. And, again, if iodide of hydrogen be brought in contact with chlorine, the iodine is expelled, and chloride of hydrogen is the result. Thus in the case of the muriatic acid, lime, and magnesia, a new combination is effected by one free body uniting with another in preference to a third, and in the last case an uncombined element brought into contact with two others in combination, tends to separate them, and by its uniting with one of them forms a new body.

Tables of the relative affinities of bases for acids, and acids for bases, may be formed; of these the following are examples: the name of the base is placed at the top of the column, and the names of the acids in the order of their affinity for it below. The bases are arranged on the same principle.

Soda.	*Muriatic acid.*
Sulphuric acid.	Potash.
Nitric acid.	Soda.
Muriatic acid.	Lime.
Acetic acid.	Magnesia.
Carbonic acid.	Oxide of iron.

Affinity is said to be *double elective* when it is exerted among a greater number of bodies than three, and where by the mutual action of two compound bodies two new ones may be formed, a double decomposition having taken place. Thus, if nitrate of lime be decomposed by potash, lime is set free and simple decomposition only occurs; but if carbonate of potash be employed double decomposition will take place, for carbonate of lime will be formed as well as nitrate of potash. The formation of a second body does not take place merely because its elements are brought into contact with each other, and have no choice but to unite; as by the exercise of double elective affinity decompositions will result which single elective affinity could not have caused, and which appear to take place even in opposition to it. Thus, nitrate of lime will not be decomposed by ammonia; on the contrary, lime will take nitric acid from ammonia; but if we mix a solution of nitrate of lime and carbonate of ammonia they will decompose each other, and by double elective affinity carbonate of lime and nitrate of ammonia will be formed. The affinities which tend to preserve compound bodies in the same condition, are called the *quiescent*, those which have the opposite tendency, *divellent*, and when the sum of the latter is greater than that of the former, decomposition must be the result.

Chemical action, however, does not result solely from the force of affinity, it is influenced to a remarkable extent by heat, electricity, cohesion, and other agencies. A weak affinity may be made to prevail over a strong one by a change of temperature; the strongest affinities may be destroyed by electricity, and cohesion exerts a considerable modifying power. We have seen that muriate of lime is decomposed by carbonate of ammonia, carbonate of lime and muriate of ammonia being the result; but if muriate of ammonia and carbonate of lime be mixed, without the presence of water, by applying heat, carbonate of ammonia and muriate of lime will be produced, which is reversing the former result. If the vapour of water be passed over iron heated to redness, oxygen, one of its elements, will unite with the iron, forming oxide of iron, and hydrogen the other element of water will be set free; but, if this oxide of iron be heated to redness, and hydrogen be passed over it, the oxygen will unite with the hydrogen forming water, and the iron will be left in its pure metallic state.

The influence of cohesion in modifying chemical affinity is exemplified in the fact, that liquidity is the particular state of matter in which decomposition is most active, though there are some remarkable exceptions to this rule, as when chlorate of potash and sulphur, both dry, are mixed, an explosion takes place from the rapidity of the decomposition. In the gaseous form chemical affinity is weakened by the mutual repulsion of the particles. The affinities of oxygen and hydrogen are powerful, but in the gaseous form they may remain in contact for an indefinite time without chemical union. Examples of this suspension of chemical action in the case of bodies in the gaseous form are numerous.

Light exerts a peculiar power over chemical affinity. Substances which, in the dark, will not re-act upon each other, combine immediately when exposed to light; the rapidity with which they combine being in proportion to the intensity of the light. Chlorine and hydrogen do not unite in the dark; but if a ray of sunshine be permitted to fall upon a mixture of these gases, chemical affinity is exerted with such violence, that the combination of the gases is accompanied with an explosion. But the most remarkable example of the influence of light upon chemical affinities is afforded by the art of *photography*, where the basis of the process is the action of light upon certain substances exposed to it under particular conditions. If a sheet of white paper be rubbed over with a brush dipped in a very dilute solution of chloride, iodide, or bromide of potassium, and after this with a brush dipped in a solution of nitrate of silver, a chloride, iodide, or bromide of silver will be formed in the substance of the paper, which becomes blackened upon exposure to light. If any opaque body be placed between a sheet of paper so prepared and the light, the part upon which the light falls assumes a dark hue, the rest of the paper, remaining unaffected by the light, presents the outlines of the opaque body, traced with the utmost delicacy and beauty. To fix this picture the compound of silver must be removed, as otherwise the colour of the entire paper would become uniform. The removal of the salt of silver is effected by brushing it over with a solution of hypo-sulphite of soda, or a strong solution of common salt, after the image has been perfected. In the process of Daguerre, and indeed in every photographic process, the principle, as the name implies, is the same.

A fact first observed by Sir Humphrey Davy will serve to illustrate the influence of electrical force over chemical affinity. If we take three glasses, numbered 1, 2, and 3, and pour into No. 1 some solution of sulphate of soda; into No. 2, some dilute sulphuric acid; into No. 3, some water; and then connect the solutions by slips of moistened amianthus, by immersing the positive wire of a galvanic battery in No. 1, and the negative wire in No. 3, the sulphate of soda will be decomposed by the electric current, and its alkali will pass into the water in the glass No. 3, while the acid in No. 2, through which it must have passed, and which has a strong affinity for it, remains in its original condition. In this case the attraction of the negative pole of the battery was more potent than the affinity of the soda for the sulphuric acid. Professor Faraday terms the decomposition which takes place in this way *electrolysis,* and the substances acted upon *electrolytes.*

COMBUSTION.

A RISE of temperature characterizes the union of bodies having a chemical affinity for each other, and when this affinity is powerful, combination takes place, with heat sufficiently intense to render the bodies luminous. This process is called *combustion.* In the familiar acceptation, when the elements of a body unite with the oxygen of the air to form new products, the union being accompanied with the phenomena of heat and light, the body is said to burn, and to be combustible, the oxygen being styled the supporter of combustion. In a strict scientific sense this definition is incorrect, as oxygen may be burned in another body; hydrogen, for instance, when it has no more share in the process as a supporter of combustion than the body in which it is burned. During combustion, as in every case of chemical combination, no particle of matter is annihilated or lost; the forms assumed may be invisible, but all the results of combustion are appreciable by weight and measurement. Slow combustion produces heat, though not to such an extent as to attract observation. A number of sticks of phosphorus placed together will warm each other sufficiently to cause them to burst into flame. If cotton or linen rags, saturated with oil or tallow, be allowed to lie in a heap, the greasy matter rapidly combines with the oxygen of the air, and the heat thus evolved will ignite the mass. This fact will serve to account for what are called spontaneous fires. The *ignis fatuus,* or *will o' the wisp,* is a result of the slow, spontaneous combustion of inflammable matter evolved upon the surface of marshes.

The causes which produce combustion are in some instances very singular. Thus, if a piece of spongy platina be plunged into a vessel of oxygen and hydrogen gases mixed in the proper proportions to form water, an explosion will immediately follow, and the formation of water will be the result. This appears to depend upon a power possessed by platina of condensing upon its surface the particles of whatever gas it may be in contact with. To exert this power the surface of the metal must not be soiled, and the larger the surface the more intense will be the action; hence the use of spongy platina, which in a small bulk exposes a large surface. The hydrogen gas lamp acts upon this principle; a jet of hydrogen gas generated by the action of dilute sulphuric acid upon a piece of zinc, is made to play upon a bit of spongy platina, within the pores of which a quantity of oxygen gas is condensed. The chemical union of the two gases gives rise to a temperature sufficient to heat the platina to redness; the jet of hydrogen is ignited and the flame may then be communicated to any other inflammable substance.

When two bodies are brought into chemical combination, combustion, where it occurs, takes place only at the point where the two substances are in contact. In the flame of a candle or lamp, combustion, properly so called, is confined to a thin layer at the surface, interior to which is the combustible material of the burning body in a gaseous, but not luminous form. This may be demonstrated by holding over the flame a piece of wire gause: that part of the flame undergoing combustion is marked by a ring of light, internal to which all is dark, though inflammable, for the vapour which passes through the wire gause may be ignited upon the other side. In the flame of a candle four distinct portions, each differently constituted, may be marked out At the base of the flame where the air is in excess and the combustion completed at once, a pale blue coloured light is observed; as the flame moves upwards the combustible material is in excess, and the most brilliant light is emitted. The temperature of flame is in every case very high, though it may not be luminous, the light emitted arising from the circumstances of the combination; thus a current of air, though it is not burning itself, may be hot enough to ignite a solid body. Hence, wherever a bright light is produced by combustion, one of the bodies must be solid, and the light is evolved by its ignition. Hydrogen and sulphur afford very little light, for the one is a gas, and the other while undergoing combustion is in a state of vapour, and the products are in both cases gaseous. The source of light in the case of a candle, is the decomposition of the inflammable vapour inside of the flame, from the high temperature: half of its carbon forms smoke, the ignition of which is the great source of light in this instance; for a body which could not form smoke could not yield much light in burning. The separation of this smoke (carbon) may be effected by placing over the flame of a candle a sheet of wire gauze below the middle of the most luminous part; the flame will become dull, and the carbon, the combustion of which would have given it brightness, passes in the form of smoke through the gauze and may be ignited on the other side. When a clear, bright light is desirable, the burning of as much of this smoke or carbon as is possible must be effected. The Argand lamp is a contrivance for this purpose; the combustion of the carbon being facilitated by the passage of a current of air through the centre of the flame, the oxygen of the air combining with the carbon: the action of the blow-pipe depends upon the same principle, and when the current of air is replaced by one of oxygen gas, the intense light is produced which is familiarly known by the name of "the Bude light." The smoke-consuming principle is applied in a variety of ways, and on a large scale, in the furnaces of manufactories.

THE LAWS OF COMBINATION.

It is a peculiar character of chemical affinity, that bodies which enter into combination under its influence, always do so in certain fixed proportions, thus distinguishing its action from cohesion, to which this rule cannot apply. The elements which enter into combination to form any compound body, chloride of sodium, for instance, combine in certain proportions, and these are found to be invariable; thus, 100 parts of chloride of sodium always contain 39·66 parts of sodium, and 60·34 of chlorine. The importance of this law is evident, for if bodies were to combine in every proportion, without any fixed rule, no accurate estimate of their character or capabilities could be made.

When a compound body is resolved into its elements, the proportions by weight of these elements have a constant relation to each other, and are, when reduced to numbers, called the combining proportions, or equivalents, of these elements. For example, if 100 parts of oxide of copper be heated in hydrogen gas, the oxygen of the oxide unites with the hydrogen, forming water, and the copper is reduced to its metallic state. In the 100 parts of oxide there were 79·83 of metallic copper, and 20·17 oxygen, which last uniting with 2·52 of hydrogen form 22·69 of water. In this case the 2·52 parts of hydrogen equally meet the combining force of the 20·17 of oxygen as the 79·83 of copper, and hence the quantities stated of hydrogen and copper are equivalent to each other. In this manner, but on a more extended and complicated scale, the combining proportions of most of the metals have been determined.

In the formation of a table of the equivalents of simple elements, oxygen has been taken as unity by one set of philosophers, while hydrogen has been adopted by another. The hydrogen scale obtained the sanction of

Sir Humphrey Davy, and has been in very general use since his time; it is also recommended by the fact, that hydrogen of all simple bodies has the smallest equivalent. The oxygen scale is regarded as most convenient in use, owing to the vast majority of bodies into which it enters as a constituent, and its number being rated at 100, simplifies calculations. In this treatise the hydrogen standard will be adopted, as the one in popular use in lectures and works on chemistry. The following table presents a list of the simple elements, with their equivalents respectively, on this scale, hydrogen being represented as 1.

Aluminum	13·7	Mercury	101·43
Antimony	129·2	Molybdenum	47·96
Arsenic	75·34	Nickel	29·62
Barium	68·66	Nitrogen	14·00
Bismuth	71·10	Osmium	99·72
Boron	10·91	Oxygen	8·01
Bromine	78·39	Palladium	53·36
Cadmium	55·88	Phosphorus	31·44
Calcium	20·52	Platinum	98·84
Carbon	6·08	Potassium	39·28
Cerium	46·05	Rhodium	52·2
Chlorine	35·47	Selenium	39·63
Chromium	28·19	Silicon	22·22
Cobalt	29·57	Silver	108·3
Columbium	184·90	Sodium	23·31
Copper	31·71	Strontium	43·85
Fluorine	18·74	Sulphur	16·12
Glucinum	26·54	Tellurium	64·25
Gold	199·21	Thorium	59·83
Hydrogen	1·00	Tin	58·92
Iodine	126·6	Titanium	24·33
Iridium	98·84	Tungsten	94·80
Iron	27·18	Vanadium	68·66
Lanthanum		Uranium	217·26
Lead	103·73	Yttrium	32·25
Lithium	6·44	Zinc	32·31
Magnesium	12·69	Zirconium	33·67
Manganese	27·72		

To determine the equivalents of compounds it is only necessary to take the sum of the equivalents of their constituents.

In the mutual decomposition of salts the principle of equivalents is fully demonstrated, and its application becomes of great practical value. For example, 130·7 parts of nitrate of barytes require for their decomposition 71·3 parts of dry sulphate of soda, and the results of the decomposition are 116·7 parts of sulphate of barytes, and 85·3 of nitrate of soda. The composition of these salts is here exhibited.

Sulphate of Barytes.	
Sulphuric acid . .	40
Barytes	76·7
	116·7

Nitrate of Soda.	
Nitric acid . .	54
Soda	31·3
	85·3

Nitrate of Barytes.	
Nitric acid . .	54
Barytes	76·7
	130·7

Sulphate of Soda.	
Sulphuric acid .	40
Soda	31·3
	71·3

It will easily be seen, that the relative proportions of the above are just sufficient to neutralize each other; and as, according to the law of equivalents, the interchange of elements invariably takes place in regular proportions, if any larger quantity of either salt were present, it would remain uncombined.

According to this rule, it is easy to determine the equivalent of any new body. If it be an acid, it may be combined with a base the equivalent of which is known; if it be a base it may be united with an acid; if a metal, with oxygen or chlorine, and so on. The compound formed by the new body in any of these cases, will, upon analysis, yield the required equivalent, which is what remains over and above the sum of the known equivalent, allowing one equivalent of each to be the subject of examination.

When bodies unite in more proportions than one, they combine in simple multiples of the equivalents forming the primary combination. The compounds of manganese and nitrogen with oxygen, are good examples of this rule, as will be seen by the following table, in which, to save fractional computation, the oxygen scale is adopted.

349·9	unite with	100	of oxygen to form	protoxide.
349·9	„	150	„	sesquioxide.
349·9	„	200	„	peroxide.
349·9	„	250	„	manganous acid.
349·9	„	300	„	manganic acid.
349·9	„	350	„	permanganic acid.

175	of nitrogen unite with	100	of oxygen to form	nitrous-oxide.
175	„	200	„	nitric oxyde.
175	„	300	„	hyponitrous acid.
175	„	400	„	nitrous acid.
175	„	500	„	nitric acid.

The relative quantities in which the oxygen unites with the manganese are in the proportion of 2, 3, 4, 5, 6, 7, and with the nitrogen, 1, 2, 3, 4, 5. In the last case the proportions of oxygen entering into the different compounds are simple multiples of the first proportion; in the compounds of manganese they are multiples of one half the quantity of oxygen in the protoxide. The different combinations in both cases are symbolically exprest thus:

NO	(Nitrous oxide.)	$Mn.O$	(Protoxide of manganese.)
NO_2	(Nitric oxide.)	Mn_2O_3	(Sesquioxide of manganese.)
NO_3	(Hyponitrous acid.)	$Mn.O_2$	(Peroxide of manganese.)
NO_4	(Nitrous acid.)	$Mn.O_3$	(Manganic acid.)
NO_5	(Nitric acid.)	Mn_2O_7	(Permanganic acid.)

The numbers attached below and to the right in this table are by some writers placed on the same line with the symbol and to the left, thus; $N + 2\ O$, $Mn + 3\ O$. Numbers so placed apply only to the symbol to which they are attached, but in other cases they are made to signify groups of symbols. Thus $3\ Mn\ O$ means three equivalents of protoxide of manganese, that is to say, three equivalents of manganese and three of oxygen in combination.

Theory of volumes. Oxygen, hydrogen, chlorine, and nitrogen in the proportions by weight which correspond to their equivalent numbers, will afford in their volumes a certain relation to each other, the volume of oxygen being half of that of each of the other gases. Iodine and bromine, converted into vapour, in quantities proportional to their equivalents by weight, have the same volume as the equivalent of hydrogen gas. Equivalent weights of arsenic and phosphorus, in the gaseous form, have a volume equal to that of the same equivalent of oxygen gas; and sulphur, under like conditions, has a volume one third of that of oxygen. An equivalent of mercury, in the shape of vapour, is in volume four times that of oxygen, and double that of chlorine and hydrogen gas. It would appear from these facts, that although the equivalents of simple elements are very dissimilar and have a very wide range, their volumes in the gaseous state bear a very simple relation to each other. This rule also applies to the compounds which these bodies form. The volumes of the united gases are in simple equivalent proportion to each other, and when the same gases unite in more than one proportion, the second proportion is a multiple of the first. When a condensation of volume takes place, the condensed volume bears a simple proportion to the volumes of the separate elements. In the formation of water one volume of oxygen unites with two of hydrogen, and the resulting volume of watery vapour is equal to the volume of the hydrogen present. One volume of nitrogen unites with three of hydrogen to form ammonia, and the four volumes are condensed into two. This rule applies to all bodies which are either gaseous or are capable of assuming the gaseous form; and, moreover, all remarks made in relation to the law of combination in multiple proportions by weight hold good with respect to combination by volume; for example, the compounds of chlorine and oxygen which are by weight — Cl. O. Cl. O_4. Cl. O_5. Cl. O_7. are by volume 2 of chlorine to 1, 4, 5, and 7 volumes of oxygen.

THE ATOMIC THEORY.

THE theory of the atomic constitution and combination of matter, as propounded by Dalton, is in all its essential points as follows: All substances are constituted of *atoms*, or indivisible particles. These atoms are of different weights, and probably of various magnitudes in different kinds of matter. When bodies combine their combination must be so effected, that one atom of one body unites chemically with one atom of another body; or one atom of the first body must unite with two, three, or four, atoms of the second; or, two atoms of the first body with three, five, or seven, atoms of the second. No intermediate degrees of combination can occur, for the atom, being indivisible, cannot enter into combination in any other proportion. The relative weights of these atoms are the equivalent numbers of the bodies combined; eight parts of oxygen unite with one part of hydrogen, by weight, to form water, because the simplest proportions in which they can combine are one atom of each, and the atom of oxygen is eight times as heavy as the atom of hydrogen; eight parts of oxygen are equivalent to 35·4 parts of chlorine, for when an atom of hydrogen leaves the atom of oxygen it combines with an atom of chlorine, which is weightier than that of oxygen in the ratio of 35·4 to 8, and the quantity must be determined accordingly. When a second atom of oxygen combines with hydrogen, it doubles the quantity of oxygen which the equivalent of hydrogen has united with, and thus, as may be shown by many examples, involves the law of multiple combination.

Dumas is of opinion, with reference to this theory, that it is possible and more in accordance with experiment to explain the laws of chemical combination, independent of all considerations as to whether combining particles are divisible or not. Dr. Kane considers that sensible masses of matter are constituted of a number of lesser masses, which again may be made up of similar constituent groups, proceeding downward to any extent, but still without involving the question of a limit to the degree of possible division; that one class of these groups of particles is represented by the equivalent numbers; and that it is possible these numbers may indicate the manner in which the chemically combining groups may be supposed to subdivide themselves in order to generate a set of groups of an inferior class.

That the theory of atoms is of immense utility in the philosophy of chemistry, by enabling us to trace to the action of a general principle the numerical conditions to which chemical affinities are subject, is undeniable; but as far the question of finite divisibility is involved, it is quite certain that no positive decision can be made, and the researches of Wollaston and Faraday have left the matter pretty much in the predicament in which Democritus and Leucippus found it.

Isomorphism. — The property which some bodies, though differently constituted, possess of assuming the same crystalline shape is termed Isomorphism. Oxide of zinc and magnesia are isomorphous; barytes and oxide of lead are isomorphous; lime is dimorphous, being in one form isomorphous with oxide of lead, and in the other with magnesia. Isomorphous bodies bear a great similarity to each other in their chemical properties, and generally follow the same laws of combination.

Catalysis.—Decompositions often take place which are not referable to the influence of affinity. An union will also take place of bodies having but little affinity for each other, when brought into contact with a body for which neither has an affinity, and which remains unchanged. Thus, when a mixture of hydrogen and oxygen are brought into contact with a clean piece of platina, the gases combine with a development of heat sufficient to ignite the metal: the platina in this case is supposed to condense the mixed gases upon its surface and thus bring them within the sphere of their affinities. This theory, however, will not account for other phenomena. For instance, if starch be boiled with dilute sulphuric acid, it will be converted successively into four different substances, and the sulphuric acid will be found the same in properties and quantity as at first. Berzelius designated this process *catalysis* in contradistinction to that of analysis, which is the result of ordinary affinity.

SIMPLE NON-METALLIC BODIES.—OXYGEN.

THIS element constitutes more than a fifth of the atmosphere and eight-ninths of all the water which exists in such large quantities upon the earth; it enters largely into the composition of most animal and vegetable substances, and forms at least a third of the weight of the mineral crust of the globe. Combustion and respiration depend upon it, and the functions of organic life, animal and vegetable, are intimately connected with its agency. It is a colourless transparent gas of specific gravity 1102·6; 100 cubic inches of it weigh 34·2 grains; its refractive index is 0·8616, air taken at a 10,000; 100 cubic inches of water take up between three and four inches of the gas. Oxygen may be obtained in a variety of ways. The one by which it is procured on a large scale is as follows:—peroxide of manganese is put into an iron bottle, to the neck of which is attached a piece of gun-barrel connected with a smaller tube. To afford free motion the tube which passes to the pneumatic trough, or the gasometer in which the gas is collected, is connected to the final tube by a caoutchouc connector. The bottle, filled two-thirds with peroxide of manganese, is placed in a common fire, or in a furnace. Some water first passes off, and often, from the presence of carbonate of lime and of ammonia, the first portions of gas are mixed with carbonic acid, or with nitrogen; these should be allowed to escape, and the gas collected only when a small tube full of it is capable of re-lighting an extinguished taper four or five times. Pure dry peroxide of manganese consists of 27·7 of manganese, and 16 of oxygen, of which 5·3 are given off: and hence 1 lb. troy of it can furnish about 700 grains, or nearly 2000 cubic inches, equal to seven imperial gallons of gas. But the quantity generally produced is not more than two-thirds of that, owing to the impurity of the peroxide of manganese found in commerce.

Peroxide of manganese yields more oxygen when acted upon by oil of vitriol, than by the application of heat. One proportion is given off, the remaining one uniting with the manganese to form protoxide, which combines with the sulphuric acid to form sulphate of protoxide of manganese, expressed in symbols thus:—$HO.\ SO_3. + Mn.\ O_2. = SO_3.\ Mn. + O$; or, in plain terms, one equivalent of water (HO.), one of sulphuric acid ($SO_3.$), forming oil of vitriol, or liquid sulphuric acid of commerce, added to an equivalent of manganese (Mn.), united with two of oxygen ($O_2.$), forming peroxide of manganese, the results of which when decomposed are one part of oil of vitriol ($HO.\ SO_3.$), one of protoxide of manganese (Mn. O.), and one of free oxygen (O.). This process is conducted by placing a flask containing the manganese in a cup of sand, over the flame of a lamp, and pouring in twice its weight of oil of vitriol; a bent tube inserted into the mouth of the flask dips into the pneumatic trough, and under the jar intended to collect the gas. When the flask is heated oxygen gas is disengaged rapidly. Towards the end of the process the water is apt to pass from the pneumatic trough into the flask, and create an explosion with the heated oil of vitriol. The results of this decomposition have been generally stated to be one part of free oxygen, and one part of sulphate of manganese, but they are correctly as follow: By a very moderate heat the sulphuric acid decomposes the peroxide ($Mn.\ O_2.$) into protoxide (Mn. O.) and permanganic acid ($Mn_2.\ O_7.$). This is decomposed when the temperature is raised into ($Mn.\ O_3.$) manganic acid; and an equivalent of free oxygen. The temperature must be raised very much to decompose the manganic acid (Mn. O_3.), into 2 parts of oxygen (O_2.), and 1 of protoxide of manganese (Mn. O.); and, accordingly, the residue in the flask is generally green from the presence of manganic acid.

Pure oxygen may be procured by heating in a flask to which a bent tube is attached a small quantity of chlorate of potash, which consists of five parts of chloric acid (Cl. O_5.), and one of potash (KO.). When heated a little above its melting point, this salt gives off all its oxygen, and chloride of potassium remains in the flask. 100 parts of the chlorate give off 39 parts of oxygen by weight, or 543 cubic inches.

Oxygen is an active supporter of combustion. If we blow out the flame of a lighted taper it will be instantly revived by plunging the taper into oxygen gas. A piece of charcoal ignited at a point, when immersed in oxygen, will burn, throwing off rapid scintillations of intense brilliancy, and the light emitted during the combustion of phosphorus in oxygen is insupportable by the eye. Bodies not combustible under other circumstances may be made to burn in oxygen. For example, if a piece of iron wire, having a small portion of lighted taper attached to the end of it, be placed in a jar of oxygen, the combustion will extend to the iron wire, and it will become oxidized with disengagement of great heat and light. So intense is the heat evolved during this process, that the iron is melted, and falls in drops from the burning wire; these drops retain heat enough to fuse themselves, even after having passed through water, into the substance of the earthenware plate, upon which the jar is usually placed, or if a drop be made by a quick motion of the jar to impinge upon the glass, it will melt its way into the glass, or even through it, if it be thin.

Oxygen is necessary to the support of animal life, the atmosphere being rendered respirable by its presence. The bright arterial blood having fulfilled its function, by depositing nutrition throughout the body, returns along the veins to the lungs, loaded with matter useless, if not injurious, to the animal economy. In the lungs, the darkened venous blood is exposed to the action of air, from which it absorbs oxygen, and, evolving carbonic acid, becomes re-arterialized. If venous blood, even out of the body, be mixed with oxygen, it will assume the characters of arterial blood. Pure oxygen is not fitted for the support of animal life, though life will be sustained longer in it than in the same measure of atmospheric air. Life in oxygen is too vivid, too active, the powers of life are exaggerated and soon expended; the animal that has lived in oxygen dies with the body in a condition of high inflammatory fever. Most of the acids contain oxygen, and it was in the supposition that the powers of conferring acid properties was peculiar to it, that the name oxygen originated, *οξυς acid* and *γενναω to beget*, being the etymology of the word.

HYDROGEN.

This element is found as a constituent of animal and vegetable matter in great abundance, and it combines with oxygen to form water; from the latter fact it derives its name (*ὑδωρ water*, and *γενναω*). The simplest form under which the decomposition of water can be exhibited, is by placing a piece of potassium in contact with it, when the metal immediately abstracts oxygen from the water, setting hydrogen free, which may be collected if the experiment be conducted under a bell-glass inverted in mercury or water; but if the process be allowed to go on in contact with air, the action is so rapid and violent, that the heat evolved inflames the hydrogen, which burns as it is liberated. The materials here used are water (HO.), and potassium (K.), the products oxide of potassium (KO. potash), and hydrogen (H.).

The ordinary mode of procuring hydrogen is by conducting a current of watery vapour over iron filings, heated to redness, in a gun-barrel. The iron filings are converted into oxide of iron by abstracting the oxygen of the watery vapour, and the hydrogen of the vapour is set free and may be collected.

By completing the circuit of a galvanic battery through water to which some sulphuric acid or common salt has been added, to make it a good conductor, the elements of water, (oxygen, and hydrogen,) are separated at opposite poles of the battery.

If filings of iron or small pieces of zinc be put into a flask containing some water mixed with one-eighth of sulphuric acid, a brisk effervescence will ensue, hydrogen will be disengaged, and the metal dissolved. In this case, zinc being the metal, zinc (Zn.), sulphuric acid (SO_3.), and water (HO.), reacting on each other, produce sulphate of zinc ($SO_3 + Zn. O.$), and hydrogen (H.), the equivalent of oxygen previously in combination with the hydrogen going to form oxide of zinc, which unites with sulphuric acid. It is only from zinc that has undergone distillation that pure hydrogen can be procured, as the zinc of commerce and iron also generally contain traces of carbon, sulphur, or arsenic, any or all of which will combine with the hydrogen, imparting to it a disagreeable odour, and colouring its flame. Potassium and zinc, in a state of very minute division, may also be taken up with the gas. To purify hydrogen obtained in this way, it may be made to pass slowly through solutions of potash and of corrosive sublimate, which will absorb the arsenic and sulphur, and through alcohol, which will deprive it of carburetted hydrogen.

Pure hydrogen burns with a very pale white flame, almost invisible in the daytime, and while burning unites with the oxygen of the air to form water. If the orifice of a jar full of hydrogen be turned upwards, and the gas be then inflamed, the entire mass will rush out and present a volume of pale yellowish flame. If, previous to ignition, it be mixed with air, an explosion will take place. Hydrogen is not a supporter of combustion, for if a lighted taper be plunged into that gas the flame will be instantly extinguished. Hydrogen is colourless, transparent, very sparingly absorbed by water, refracts light strongly, and in its capacity for heat exceeds all other gases. It is the lightest element known, being one-fifteenth of the weight of air. It has been used to fill balloons, but as coal gas is much more easily procured, it is now generally applied to that purpose, for, though heavier than hydrogen, it is much lighter than air.

When two volumes of hydrogen are burned with one of oxygen water is formed. A mixture of hydrogen and oxygen may be exploded by the electric spark. In this process an instrument called an eudiometer is used, formed of a strong glass tube perforated by two opposite wires. The gases being confined in this tube are exploded by passing an electric spark across the wires, and if the gases have been in the due proportions for forming water, the tube will be filled with vapour, which, after a short time, will be deposited on the sides of the tube. Hydrogen and oxygen may be made to form water without exploding, or even undergoing any perceptible combustion by transmitting them through a tube heated nearly to redness, and if the tube contain sand, or coarsely-powdered glass, this union will take place at a much lower temperature. Slips of gold and silver tend to promote the combination even more strongly than sand and glass, and platinum effects the union at ordinary temperatures.

The most intense heat that can be produced by artificial means is that evolved during the combustion of hydrogen and oxygen. This heat is applied by the instrument called the oxyhydrogen blowpipe. The apparatus should be so constructed as to prevent the risk of explosion. This is best effected by connecting two tubes from distinct gasometers, or bags of gas, near to the point where the jet is to be formed, and the jet will be perfect if it consist of two volumes of hydrogen and one of oxygen, the latter being made to pass through a hollow cylindrical jet of the hydrogen, which is effected by an arrangement of the tubes.

For experiments on a small scale Hemming's apparatus is the best, all risk of explosion being prevented by its use.

The most obdurate substances yield to the influence of the oxyhydrogen flame: flint, pipeclay, even platinum, are not merely fused but apparently vaporised; iron burns in it with more brilliancy than in oxygen. Some of the earths resist its power, and of these lime and magnesia, the first especially, become so luminous as to rival if not exceed in brightness the most intense solar ray, for which the oxyhydrogen lime light, or "Drummond light," is commonly used as a substitute in optical as well as chemical experiments. The light evolved by the oxyhydrogen jet playing on a piece of lime, has been distinctly visible at seventy miles' distance.

It was until recently the generally received doctrine, that hydrogen had the same property with reference to one set of bases that oxygen has with another, namely, the power of generating acids with them, the acids so formed being termed hydracids; for instance, hydrochloric acid, in the formation of which hydrogen was supposed to bear the same relation to chlorine that oxygen has to sulphur in sulphuric acid. From this Dr. Kane was the first to dissent. His researches go to prove, that hydrogen is an eminently electro-positive body, that it takes a place along with iron, manganese, and zinc, and that the compounds of hydrogen with chlorine, iodine, and sulphur, are almost universally electro-positive, and possess basic characters derived from the high positive energies of the hydrogen itself. The investigations of Professor Graham have corroborated these views, and no doubt appears to exist that hydrogen is closely allied to the metals, especially to zinc and copper; that the chlorides, iodides and fluorides of hydrogen, though possessing some of the characters of acids, also closely resemble the chlorides, iodides and fluorides of zinc and copper; that, in short hydrogen is essentially a metal of immense volatility, but possessing all the true chemical peculiarities of metals, and "no more deprived of the common qualities of lustre, hardness, or brilliancy, than is the mercurial atmosphere which fills the apparently empty top of the tube of a barometer, or the salivating air of a quicksilver mine, or of a gilder's workshop."

WATER.

PURE water consists of two proportions of hydrogen and one of oxygen in volumes, and by weight one part of hydrogen to eight of oxygen, or of 11·1 of hydrogen and 88·9 of oxygen in 100 parts. These proportions are ascertained by passing hydrogen over chloride of calcium in order to thoroughly dry it, and then over black oxide of copper heated to redness. The oxide of copper is reduced to a metallic state, and its oxygen combines with the hydrogen to form water. Water is assumed to be composed of an equivalent of each of its constituents, and its atomic weight is one atom of oxygen 8 + one of hydrogen = 9; it is transparent, colourless, and destitute of taste and smell. It freezes at 32 F., but may be cooled much lower without solidifying if kept perfectly quiet; if then shaken it forms ice, and its temperature is raised to 32°; in freezing it exerts a tremendous expansive force. Water is converted into vapour at 212°, the specific gravity of which is 620·1, air being 1000. Two volumes of steam contain two of hydrogen and one of oxygen. According to Gay Lussac, water in forming steam at 212°, and at a pressure equal to 30 inches of mercury expands to 1696 times its volume, a cubic inch of water forming almost a cubic foot of steam, or 1728 cubic inches.

Gases are absorbed by water in variable quantities: in some cases, as with muriatic acid gas and ammonia, chemical union takes place; in others, the particles of the gas are merely mechanically mixed with the fluid.

The agreeable taste of water is owing to the atmospheric air which it contains in solution; this is driven off by boiling, and if it be intended to saturate water with any gas the air it contains should be expelled in this way, as the presence of a very small portion of air will diminish very much the power of absorption on the part of the water.

Water enters into chemical combination with very many substances. Most salts in crystallizing retain water,—this is termed water of crystallization, and is driven off by the application of heat, the salt being in many instances dissolved in its own water of crystallization, or, as it is called, undergoing watery fusion. Crystals which attract more water from the atmosphere are said to be *deliquescent;* those which lose their water of crystallization and fall to powder are called *efflorescent.* Professor Graham is of opinion that salts, in addition to their water of crystallization, contain water which remains when that of crystallization is driven off, and which is essentially necessary to their constitution, and only parts from them when they enter into combination with other bodies. Thus, from crystals of sulphate of copper four proportions of water may be driven off by a temperature of 150°, whilst a fifth resists a heat of 300°; this fifth is removed when the salt combines with another, and is called the constitutional water of the salt.

Water acts the part of a base in combination with some of the more powerful acids; many are only recognised in union with it, such as the nitric, chloric, oxalic, and acetic, which cannot be obtained separate from water. Sulphuric acid of commerce, or oil of vitriol, is a sulphate of water, and such salts of water bear a complete similarity to those of zinc and copper.

Water enters into combination also with bases, often with evolution of much heat. The heat evolved during the combination of dry lime with water, or the slaking of lime as it is called, is sufficient to ignite gunpowder, and if the mass be considerable a red heat will be produced. Ships laden with lime have been set on fire in this way by the accidental influx of water. The evolution of heat is still greater during the combination of water with strontia and barytes. In relation to these bases water appears to play the part of an acid.

The compounds of water are usually termed *hydrates*, as hydrate of lime, hydrated sulphuric acid; and substances destitute of water are called *anhydrous*. Water naturally contains a number of impurities; of these the most general are air, carbonic acid, common salt, sulphates and carbonates of lime, and chloride of magnesium. Some springs are found to contain iron, and often sulphuretted hydrogen, also traces of bromine and iodine, &c.; and where these are contained in sufficient amount the water is used for medicinal purposes, and is termed mineral or spa water. As mineral matter is taken up during the percolation of water through the different strata it may have passed, rain and snow-water are the purest natural water; and even these contain air and carbonic acid in solution, so that, for chemical purposes, water must be distilled. The sea, as the reservoir of all the rivers of the globe, holds in a state of concentration all the mineral solutions borne into it, and is the source in many places whence common salt and sulphate of magnesia are derived; it is nearly similar everywhere, or, if not, the difference can be accounted for by local influences.

The saline impurities of water may be detected by the re-agents which act on them separately,—thus, if it contain common salt, it will give a white precipitate with solution of nitrate of silver; if lime, a precipitate with oxalic acid; if salts of sulphuric acid, nitrate of barytes will throw down a precipitate.

Water is taken as a standard in calculating the specific heats and gravities of solids and liquids.

Peroxide of Hydrogen.—($HO. + O.$ or $HO_2.$). We are indebted to Thenard for the discovery of this substance; and as hydrogen and oxygen do not combine directly in any other proportions than in those that form water, its preparation is indirect. Peroxide of barium must first be prepared, by passing a stream of oxygen gas over pure barytes (oxide of barium), heated to redness in a porcelain tube as long as any may be absorbed: the oxide of barium will absorb as much more oxygen as it had before. This is added to hydrofluoric acid until the acidity of the liquor is quite neutralized; the fluorine combines with the barium, and all the oxygen is transferred to the hydrogen, or in symbols thus: $HF. + Ba. O_2. = Ba. F. + HO_2.$ The fluoride of barium is insoluble, and the filtered fluid contains oxygenated water, or peroxide of hydrogen. This is concentrated by placing it in the exhausted receiver of an air-pump beside a capsule of sulphuric acid; the water being more volatile, will evaporate and be absorbed by the sulphuric acid, leaving the pure peroxide behind. It is a thick, colourless liquid, sp. gr. (specific gravity) 1·452; has a nauseous taste, and irritates the skin, bleaches and destroys all vegetable colours, and its re-actions upon other substances take place with such violence, that, to be experimented on, it must be diluted. There are a great many solid substances, by contact with any one of which it is rapidly resolved into oxygen and water; black oxide of bismuth, gold, silver, platinum, and mercury, have this action upon it, as also have the oxides of these metals; in this case the metal and oxygen are both set free. Peroxide of hydrogen is decomposed by animal fibrine, but not by albumen, thus serving to distinguish between two substances bearing a close resemblance to each other. When kept for some time, even diluted, it is decomposed, oxygen being freed, and water remaining; the presence of an acid retards this action, and that of an alkali accelerates it.

NITROGEN (N.),

NAMED from its being the basis of nitric acid and nitre, is also frequently called *azote* (*α without* and *ζωη life*), from its incapacity to support life. It may be procured from atmospheric air by the action of any substance that will absorb the oxygen. If a small piece of phosphorus be ignited over water and under a bell-glass, it unites with the oxygen of the air, forming white fumes of phosphoric acid, which will be absorbed by the water,—the gas remaining is nitrogen. Any burning body will effect this decomposition, though not so completely as phosphorus. Nitrogen may be obtained from most animal substances in which it exists, combined with carbon, oxygen, and hydrogen. If a piece of muscle be boiled in a retort with nitric acid, the carbon and hydrogen of the animal substance will unite with the oxygen of the nitric acid to form various compounds, nitrogen being released from both bodies. If a current of chlorine be made to pass through ammonia, salammoniac is formed, and nitrogen disengaged: thus, ammonia consists of one equivalent of nitrogen and three of hydrogen; the latter unite with three of chlorine to form three of hydrochloric acid (muriatic acid), which unite with three of ammonia to form salammonaic (muriate of ammonia), leaving one equivalent of nitrogen disengaged; in symbols, — $1\ NH_3$ and $3\ Cl.$ give $1\ N.$ free, and $3\ Cl.\ H.$, which combine with $3\ NH_3$ to form $3\ ClH.\ NH_3$

Nitrogen is a colourless transparent gas, very sparingly absorbed by water, lighter than atmospheric air, its sp. gr. being 976, air being 1000; it is not a supporter of combustion or respiration, as animals are killed by it, and the flame of a taper is extinguished in it. These effects, however, are ascribed to the absence of oxygen. Nitrogen unites indirectly with oxygen to form a number of important compounds; one of these, nitric acid, is the one most generally formed. The electric spark will effect the union of the gases to form this acid if water or alkaline solution be present, hence the occurrence of nitric acid in rain-water after a thunder storm, and the neutralization by nitric acid of lime and potash in old walls. Spongy platinum, at a temperature of 572°, will convert ammonia and oxygen into nitric acid and water. The combining equivalent of nitrogen is 14·0.

THE ATMOSPHERE.

PURE atmospheric air, in 100 parts by weight, consists of oxygen gas 23·04 parts, and of nitrogen gas 76·96 parts, = 100·00. There is always present, however, in atmospheric air some carbonic acid and watery vapour. According to the calculations of Saussure, 10,000 volumes of air generally contain 4·15 of carbonic acid, the maximum being 4·74, and the minimum 3·15. Over the surface of lakes the quantity is diminished, over cities increased, averaging 4·46: the amount is somewhat greater in the night-time than in daylight, and in the higher regions of air than on the surface of the earth. Traces of carburetted hydrogen have been found in atmospheric air by Saussure and Boussingault.

To demonstrate the quantities of nitrogen and oxygen in atmospheric air, it is only necessary to act upon it with any of the bodies which absorb oxygen. Scheele used a solution of sulphuret of potassium, which when exposed to the air absorbs oxygen, and is gradually converted into hyposulphite of potash, the quantity of oxygen being ascertained by the amount of absorption. There are many methods, however, of determining this point, which it is not necessary to detail here.

The constitution of air appears to be the same at all heights, at least, the experiments of Gay Lussac and Brunner support this view; the former having experimented upon some which he brought down by a balloon from a height of 21,735 feet, and Brunner's analysis having been instituted upon air 8·020 feet above the level of the sea.

Many circumstances led to a belief that air was a chemical compound of its elements and not a mixture, and it was supposed to consist of one volume of oxygen and four of nitrogen; and it was, moreover, alleged, that if they were merely mixed the heavier gas would occupy the lower strata of air. To disprove this, it is only necessary to remark, that the elements of air are separated with great facility indeed; for instance, by agitation with water, by nitric oxide, by metallic lead, &c., which in the most feeble chemical combination could scarcely exert such a power; and again, that the density, refractive power, and specific heat of air, are the mean of the gases which form it, which is the necessary result of a mixture, but not of any case of chemical combination; and, finally, that an artificial mixture of oxygen and nitrogen possesses all the properties of atmospheric air. It may be proved also by experiment, that mixed gases do not gravitate in proportion to their densities, but evince a disposition to mix with each other strong enough to overcome the force of gravitation. If two bottles filled with gases of different densities be placed one above the other, that containing the heavier gas being lowest, and if means of interchange of contents be provided, the heavier gas will after some time be found in the upper bottle, and the lighter will have made its way into the lower one. This power of penetrating into the spaces occupied by each other is exerted by gases even when obstructed by the interposition of a membrane, or by masses of porous substances. If a glass be filled with hydrogen, and the top being closed by a sheet of Indian rubber, a bell glass be placed over it, the hydrogen will pass out of the glass more rapidly than the air will supply its place, and the Indian rubber will be bent into the glass, and ultimately burst by the pressure of the air; if the glass contain air, and the bell glass hydrogen, the Indian rubber will be forced up by the excess of hydrogen which passes in. The exact law of the diffusion of gases, as assigned by Professor Graham, is, that the velocity of diffusion is inversely proportional to the square roots of the specific gravity of the gases.

By the operations of combustion and animal respiration the atmosphere is being constantly deprived of oxygen, and carbonic acid is formed at the same time. Carbonic acid being destructive to animal life, air is rendered unfit for respiration before half its oxygen is consumed.

A healthy adult vitiates 720 cubic feet of air in twenty-four hours; the same effect is produced by the combustion of three ounces of charcoal. From these facts the use of winds and storms is obvious, as without the incessant agitation to which the atmosphere is liable, the noxious elements so developed would accumulate in certain localities, and destroy all animal existence wherever such accumulation should take place; but when these impurities are dispersed, they bear a small proportion to the vast extent of the air we live in. Another principle, however, is constantly at work in the vegetable kingdom, by which the air is retained in a state fitted to support animal life. The surfaces of the green leaves of plants are, when exposed to the sunlight, continually absorbing carbonic acid, and evolving oxygen; but in the dark this process is reversed, and the coloured parts of plants also absorb oxygen, and give out carbonic acid. The action of the green surfaces, however, being on a much more extended scale, and the time that action is continued being of prolonged duration, the purifying influence of plants neutralizes the results of animal respiration.

One hundred cubic inches of air, free from watery vapour and carbonic acid, weigh 31·0117 grains. Its sp. gr. is taken as the standard for gases and vapours, and is rated at 1000; it is about 780 times lighter than water, at its greatest density (40·5° F.). The pressure of the atmosphere upon each square inch of the earth's surface is equal to about fifteen pounds' weight. This pressure is equivalent to that of a column of mercury 30 inches high, and upon this principle the barometer in common use is constructed to indicate the pressure which the atmosphere exercises at different times.

In making a barometer the following general conditions are secured:—A tube about 32 inches long, closed at the end, is filled with purified mercury and then inverted in a vessel of mercury; the tube being placed in a vertical position, the mercury in it will stand at a height of from 29 to 30 inches, according to the pressure of the air. The space between the top of the tube and the surface of the mercury in the tube is called the Torricellian vacuum, from Torricelli the inventor of the instrument, and though filled with a subtile vapour of mercury it is at a low temperature the nearest approach to a perfect vacuum that can be procured. The height of the mercury in the tube will vary as the pressure of the atmosphere upon the surface of the mercury exposed to it varies; this variable pressure depends upon the motions of the air, and as these are followed by changes in the weather, the variations in the height of the mercury are supposed to portend storms, rains, and other changes in the condition of the atmosphere; but the barometer is by no means an unerring oracle.

The atmosphere decreases in density in a regular proportion to its height; the lowest portion being pressed upon by the superincumbent mass is the most dense. If it were of the same density throughout, its height would be about five miles. Upon the principle of a diminution of density in the air the exact height of mountains may be ascertained. The column of mercury in a barometer will be shorter on the top of a mountain than on the plain, and the difference being marked and then compared with the known diminution of density the height may be determined. The diminution of density is so rapid, that one half of the entire mass of air is contained within the space of three miles from the surface of the earth, and four-fifths of it within eight miles. The sense of lassitude, the headaches, and other unpleasant sensations experienced by those who have ascended to considerable altitudes, are ascribable to the rarity of the air—the lungs in this case not receiving a sufficient supply of oxygen to arterialize the blood. Lakes in elevated situations, such as the Andes, do not contain fish, as the water holds no air in solution. That the absence of fish is owing to this cause may be demonstrated by placing a fish in a vessel of water under the exhausted receiver of an air-pump; the air being abstracted the fish dies.

From the refractive power of the atmosphere it is estimated to extend forty-five miles above the earth's surface, or, more correctly, above the level of the sea; or if it extend beyond this limit, it has no power to refract a ray of light. A ray may pass close to any of the other planets of our system without suffering deflection from its direct course, which proves the non-existence of atmospheres around them, a condition which could not exist if one atmosphere extended through all space, as each planet should have an atmosphere of density proportioned to the mass of the planet involved in it.

Nitrous Oxide, popularly called "laughing gas," is easily prepared by heating crystallized nitrate of ammonia to about 350° F., when the salt is resolved into protoxide of nitrogen, or nitrous oxide and watery vapour, one equivalent of the nitrate giving two of the gas, and four of water thus: NO_5. (nitric acid) + NH_3. (ammonia) = 2 NO (two of nitrous oxide) + 4 HO. (four of water). The process may be conducted in a flask with a bent tube attached, one end terminating under a receiving-jar placed in a pneumatic trough, the jar being supplied with a stop-cock at top, to allow the passage of the gas into an empty bladder furnished with another stop-cock. The flask may be placed in a cup of sand, or the flame of a spirit-lamp may be applied to the naked flask; but the heat must not be above 350°. As water absorbs the gas to some extent, the water in the trough must be at 90°, the increased temperature depriving it of much of its capacity for absorption. The specific gravity of NO. is 1·527; a lighted taper burns with increased brilliancy in it, and when blown out may be re-lighted if a large portion of the wick be red. Phosphorus burns in it with almost as much brilliancy as in oxygen; but the gas does not enter into combination in such cases, the combustion being supported by the oxygen disengaged during its decomposition. Mixed with its own volume of hydrogen it will burn with an explosion by contact with the electric spark or the flame of a taper.

This gas when breathed for a few minutes produces singular sensations, in many cases analogous to intoxication, but leaving none of the disagreeable results of ordinary intoxication behind. To produce this effect the gas must be pure; for if the salt contain muriate of ammonia, as it frequently does, great irritation of the lungs will be caused by the chlorine and nitrous acid formed in such cases, About two ounces of nitrate of ammonia will produce gas enough to intoxicate one person, that is, from four to five quarts, which must be inspired from a bag or bladder, through a pretty wide glass tube, compressing the nostrils at the same time.

Nitric Oxide, or Deutoxide of Nitrogen (NO_2.), is produced during the decomposition of nitric acid by the metals. If dilute nitric acid be poured upon mercury or copper in a flask, the metal will be dissolved, the solution being pale green if mercury be employed, and dark blue in the case of copper. Reddish fumes are first evolved, and when these pass off the colourless gas may be collected in the usual way. In this decomposition the nitric acid gives three-fifths of its oxygen to the copper, forming oxide which unites with undecomposed acid to form nitrate of copper, the remaining two-fifths of oxygen forming nitric oxide with the nitrogen, thus: NO_5. and Cu. give $NO_5. + Cu. O.$ (nitrate of copper) and NO_2. (nitric oxide). Lighted phosphorus will burn in the gas nearly as brilliantly as in oxygen; but the contact of a red-hot wire will not inflame it in the gas. A lighted taper is extinguished in this gas, and combustion is supported only by the oxygen liberated during its decomposition. Its specific gravity is 1·039. NO_2. has a strong tendency to unite with uncombined oxygen, forming nitrous or hyponitrous acid, which is the cause of the deep red fumes given off during the action of nitric acid upon mercury or copper, the NO_2. uniting with the oxygen of the air in the flask. These red fumes are soluble in water.

Hyponitrous Acid (NO_3.). Four volumes of nitric oxide mixed with one of oxygen form pure hyponitrous acid vapour, which when exposed to a temperature of 40° below the freezing point of water is condensed into a deep green-coloured very volatile liquid. This acid forms salts with bases which are called hyponitrites. Nitre when kept melted for some time is reduced from the state of nitrate to that of hyponitrite of potash, which is recognised by the action of acetic acid producing red fumes.

Nitrous Acid (NO_4.). This acid is formed in the shape of deep red fumes when oxygen is in excess with nitric oxide; at 0° F., it is rendered liquid. It may be prepared by mixing four volumes of nitric oxide with two of oxygen, or more conveniently by the decomposition, by heat, of nitrate of lead. Fluid nitrous acid at 60° is orange yellow, nearly colourless at zero; at − 40° it forms a white crystalline mass; boils at 82° with a red vapour, which becomes nearly black at 212°; its sp. gr. is 1·451. NO_4. is the most stable compound of nitrogen and oxygen, as it will resist a red heat; when mixed with water nitric acid is formed, and nitric oxide given off. It forms salts with bases.

NITRIC ACID (NO_5.).

Four volumes of nitric oxide mixed with three of oxygen over water combine, forming red fumes, which, when dissolved in the water, afford a solution of nitric acid. The union of nitrogen and oxygen in the atmosphere, in proper proportions to form nitric acid, is the great natural source of nitric acid. That this is brought about by electrical agency may be presumed from the fact, that if a succession of electric sparks be passed through air confined over a solution of potash, the latter will be converted into nitrate of potash (saltpetre). Nitrate of ammonia is found in rain-water after a thunder-storm, the nitric acid formed in the atmosphere having combined with ammonia evolved during the decomposition of animal matter on the earth. In the East Indies, ammonia is produced in large quantities by the rapid decomposition of animal matter; the ammonia is then converted into nitrate of ammonia in the atmosphere. This is distributed by the heavy rains over porous calcareous surfaces; the ammonia is expelled by the stronger affinity of the alkaline bases of the soil for nitric acid; nitrates of potash and lime are thus formed,—the latter in large quantities. The nitrate of lime is converted into saltpetre by carbonate of potash, and constitutes an important article for export. Artificial nitric beds are formed on the Continent upon this principle, to supply saltpetre for the manufacture of gunpowder. Nitrate of soda is largely imported into this country from South America, where it is found in many districts naturally formed.

Nitric acid is found only in combination, never having been isolated. The fluid popularly called nitric acid, which is a combination of nitric acid and water, is obtained by applying heat to a mixture of equal parts of nitre and of oil of vitriol in a glass retort; the sulphuric acid of the oil of vitriol unites with the potash, giving its water to the nitric acid, which is distilled over into a cold receiver. Double the quantity of sulphuric acid is used here that is necessary to saturate the potash, for if not, an adhesive mass of bisulphate of potash and nitre would remain in the retort, from which it could not be extricated without risk of breaking the glass.

If the temperature be increased to 400°, the quantity of oil of vitriol barely necessary may be used; but the neutral sulphate of potash which remains cannot easily be released from the retort, and the higher temperature required incurs the risk of breaking the glass. The material which is now principally used, and which yields the largest product, is nitrate of soda, the distillation being conducted on the large scale from iron retorts connected with condensers. The strongest fluid nitric acid consists of one equivalent of nitric acid (NO_5.) 54·0, and one of water (HO.) $9{\cdot}0 = 63{\cdot}0$, and has a sp. gr. of 1·521; it boils at 157°, and is partially decomposed during distillation. It is not usually so strong as this. It is colourless when pure, fumes in contact with the air, and when exposed to the solar ray is changed into nitrous acid and oxygen, assuming a deep yellow hue; it acts with great rapidity on the generality of metals and organic bodies, giving its oxygen to them, and leaving nitric or nitrous oxide free, and, in some cases, pure nitrogen. With organic substances not containing nitrogen it forms oxalic and carbonic acid, and with animal matter, compounds of a yellow colour, as is observed on the skin when touched lightly with it. Fluid nitric acid often holds nitrous acid in solution, which imparts to the whole a deep red or orange colour. Nitric acid is liable to acquire chlorine, sulphuric acid, and iron. By mixing a few drops of the acid with distilled water sulphuric acid may be detected if a precipitate be formed with solution of nitrate of barytes; solution of nitrate of silver will afford a precipitate if chlorine be present; and if iron be present, a blue precipitate (Prussian blue) will be formed with solution of prussiate of potash. Redistillation will deprive the acid of these impurities. NO_5. may be recognised in several ways: when in contact with a metal, it produces red fumes of nitric oxide; if a drop of the acid be added to water tinged blue by sulphate of indigo, and the mixture be then boiled, the indigo will be oxidised by the acid, and the liquor bleached; if a crystal of protosulphate of iron be placed in contact with water containing nitric acid, a deep olive-coloured ring will form round it as it dissolves, one part of the salt converting the acid into nitric oxide, which combines with the remaining protosulphate. NO_5. enables muriatic acid to dissolve gold leaf, but this property is not peculiar to it; it gives a deep red colour with morphia. The best mode of detecting NO_5. in solution, is to neutralize the liquid with potash and evaporate it to dryness; the sharp needle-like crystals which form deflagrate on ignited charcoal; heated with a small portion of bisulphate of potash and copper-filings, it evolves red fumes, and with a crystal of protosulphate of iron, and a drop of sulphuric acid, forms the olive-coloured ring before mentioned. All solid compounds with NO_5. may be recognised in this way.

SULPHUR (S.).

THIS element exists largely in nature, both alone and in combination; it is found in ores of copper, lead, silver, mercury, antimony, and much of the sulphur of commerce is procured from bisulphuret of iron (iron pyrites). Native sulphur is the produce of volcanic exhalations, and is found condensed in fissures of the earth. It exists in combination with oxygen forming native sulphates, as sulphate of lime (gypsum), and of barytes. Sulphur is found as a constituent in the white and yolk of eggs, in the hair, horns, and hoofs, of animals, and in black mustard-seed. The sp. gr. of sulphur is 1·98; it melts at 226° into a thin amber-coloured fluid; at 400° it becomes opaque, dark brown, and so thick, that the vessel containing it may be inverted and still retain it; if suddenly cooled whilst in this state by immersion in water it forms a plastic mass: with a further increase of temperature it becomes thin, and boils at 601°. Roll sulphur is made by pouring the crude native sulphur into moulds; flowers of sulphur are very minute crystals, formed by the condensation of the vapour of sulphur; milk of sulphur is the result of precipitation from solutions in which it existed in combination. Sulphur dissolves in oils, alkaline solutions, and in milk of lime, but not in water or in alcohol; it combines with oxygen to form sulphurous acid, sulphuric acid, hyposulphurous, and hyposulphuric acid.

Sulphurous acid (SO_2.) is always produced when sulphur is burned in air or in oxygen, sulphur not being directly capable of further oxidation. It is gaseous at the ordinary temperature and pressure, but is very easily reduced to the fluid state. By heating three parts of sulphur with four of peroxide of manganese, sulphurous acid gas is readily formed; one part of sulphur unites with the metal, and another with the oxygen, to form sulphuret of manganese and sulphurous acid ($Mn. O_2. + 2 S. = Mn. S. + SO_2.$). The gas is absorbed by water, and, for examination, should be collected over mercury; it is colourless and transparent, has a very irritating odour, and is irrespirable, is not combustible, nor a supporter of combustion; it bleaches many vegetable and animal substances, such as straw, silk, and sponge; but this effect is not permanent, as the white compound formed by the coloured substance with the acid loses the latter, and the colour is restored. In such cases, the acid may be driven off by a stronger one; for example, if a red rose be bleached by exposure to the vapour of burning sulphur, its odour will be restored by washing in dilute sulphuric acid. The sp. gr. of $SO_2.$ is 2210·6; exposed to a temperature of 0° F., it is converted into a fluid heavier than water, which boils at 14°, and produces intense cold by its evaporation.

SULPHURIC ACID ($SO_3.$).

THIS acid is formed by the combination of sulphurous acid with another equivalent of oxygen, and not in any instance from the direct union of sulphur and oxygen. It is prepared on a large scale for the purposes of commerce, by bringing sulphurous acid produced by the burning of sulphur into contact with watery vapour and nitrous acid fumes; these form a white crystalline mass, which appears to consist of sulphurous and nitrous acids, with sulphuric acid and water in uncertain proportions. This substance is decomposed by contact with water, forming sulphuric acid and nitric oxide; the latter unites with the oxygen of the air to form nitrous acid fumes, which combine with fresh portions of sulphurous acid gas. The apparatus in which this process is conducted consists of a long leaden chamber, the lower portion of which is a tray of about 1½ foot deep, the upper of a quadrangular form, which being suspended on a wooden frame-work, rests with its edges in the liquid with which the tray is covered. The bottom of the tray has an oblique direction, so that the fluid in it is deeper at one end than at the other; outside and underneath is placed a furnace, on which the sulphur is burned, the sulphurous acid gas passing into the chamber by a chimney; the nitrous acid is obtained by placing a pan, holding nitrate of soda or of potash, and oil of vitriol, over the burning sulphur; the nitric acid evolved gives a portion of its oxygen to part of the sulphurous acid, and is thus reduced to the state of nitrous acid, which acts upon the mass of sulphurous acid. Provision is made for the admission of steam into the chamber, so that the white crystalline solid before mentioned is continually being formed, by the combination of sulphurous and nitrous acids and watery vapour, which, when decomposed by the water in the chamber, is resolved into sulphuric acid and nitric oxide gas. The NO_2 mixes with the atmospheric air of the chamber, and taking its oxygen again forms nitrous acid gas, which, uniting with a new portion of sulphurous acid, forms the white crystalline mass, Nitrous acid fumes and air being supplied continually as the process goes on, until the fluid at the bottom of the chamber holds a sufficient amount of acid in solution to be decanted off. Owing to the obliquity of the leaden floor, the heavier portions of fluid gravitate to one end whence they are removed by leaden pipes. When a sp. gr. of about 1·600 has been attained, it is then concentrated by evaporation in leaden vessels to a sp. gr. of about 1·76, after which it is transferred to vessels of glass or platinum, the lead being no longer capable of resisting its action, combined with that of the temperature necessary. The strongest acid that can be thus obtained has a sp. gr. of 1·847, and contains 81·54 of real acid in 100 parts of fluid.

The practice of burning iron pyrites instead of sulphur has been introduced, and is now in extensive use, the apparatus being altered to suit the purpose.

Sulphuric acid is prepared in a different way on the Continent. This is called Nordhausen or fuming SO_3., and is of a much stronger quality than that procured by the combustion of sulphur. It is obtained by exposing sulphate of iron (copperas), not quite deprived of its water of crystalization, to a red heat in earthen retorts; the acid unites with the water, and being distilled over, forms a dark-coloured, thick, oily fluid, of sp. gr. 1·9, consisting of about 90 of real acid, and 10 of water in 100 parts. The fumes which characterize this acid are formed by the union of watery vapour, with the colourless and volatile vapour of sulphuric acid given off, producing liquid acid. If the colourless vapour be received in a dry vessel, and cooled by a freezing mixture, beautiful white fibres of dry SO_3. are formed. The acid prepared in leaden chambers is liable to contain nitric acid and lead; from these it is freed by redistillation. Sulphate of lead is generally deposited from diluted oil of vitriol, having been held in solution by the stronger acid. The acid formed from iron pyrites is found to contain arsenic and selenium.

SO_3. may be detected by a solution of nitrate of barytes, throwing down a white precipitate insoluble in boiling muriatic acid. When mixed with $\frac{1}{4}$ of its weight of water, both at 50°, the temperature is raised to 300°, and a condensation of volume takes place. This acid has a powerful affinity for water, and will become diluted if exposed to the air, by absorbing watery vapour. SO_3. of the sp. gr. of 1·780 freezes at 32°, but if stronger or weaker requires a very low temperature to solidify. The colourless acid is blackened by contact of any carbonaceous substance, such as a bit of cork; the hydrogen and oxygen form water, which unites with the SO_3., leaving carbon free. The colour may be discharged by boiling, as the carbon will take oxygen from part of the SO_3., forming carbonic acid and sulphurous acid, which are expelled.

Hyposulphurous acid. (S_2. O^2. or SO_2. + S.). —

When sulphur is boiled with an alkaline liquor, or with milk of lime, this acid is formed; thus, when sulphur and soda are boiled in water, hyposulphite of soda and sulphuret of sodium are produced. This acid is very easily decomposed; it may be obtained in a free state, by adding a stronger acid to any of its salts, or by reaction of sulphuretted hydrogen and sulphurous acid upon each other, in water. The compounds of hyposulphurous acid possess the power of dissolving certain combinations of silver insoluble in water, as the chloride and iodide, and form a solution of a very sweet taste. Their use in photographic processes depends upon this property. The salt which this acid forms with silver, when boiled, is resolved into black sulphuret of silver and free sulphuric acid, and it is capable of forming salts with metallic sulphurets as well as oxides; for there are two hyposulphites of sodium, one of which contains soda (oxide of sodium), the other sulphuret of sodium.

Hyposulphuric acid ($S_2. O_5.$).—By passing sulphurous acid gas through water in which peroxide of manganese is diffused, the latter will be dissolved, and the solution will contain hyposulphate of manganese: one atom of oxygen of the peroxide converts two equivalents of sulphurous acid into hyposulphuric, which unites with the protoxide of manganese. A salt of this acid when heated is resolved into sulphurous acid and a neutral sulphate. The acid may be obtained free by decomposing hyposulphate of barytes by sulphuric acid; but it is not permanent.

Sulphuretted hydrogen, or sulphuret of hydrogen (HS.). By acting upon proto-sulphuret of iron with dilute sulphuric acid, HS. and sulphate of protoxide of iron are formed. Water is decomposed, its oxygen uniting with iron, and its hydrogen with sulphur. HS. may also be obtained by the action of dilute sulphuric, or muriatic acid upon sulphuret of potassium; and the action of muriatic acid upon sulphuret of antimony produces pure sulphuret of hydrogen, thus: $Sb_2. S_3.$ (sulphuret of antimony)

$+ 3\ H\ Cl.$ (hydrochloric, or muriatic acid) $= Sb_2.\ Cl_3. + 3\ HS.$ The gas being absorbed by water must be collected over water which has had its absorbing power diminished by being heated to 90°. HS. gas is transparent and colourless; its sp. gr. is 1177, and it is easily recognised by a peculiarly fetid odour, that of rotten eggs, the odour of which is owing to the formation of this gas during their putrefaction. HS. dissolved in water throws down sulphurets from the solutions of most metallic salts; with antimony it forms an orange red precipitate; with manganese a flesh red, with arsenic a canary yellow, and with lead, mercury, &c., black or brown. HS. is very inflammable; if the combustion occur in a small portion of air the hydrogen is consumed and sulphur deposited; nitric acid and chlorine completely decompose it, hence the disinfecting properties of these substances. It is very destructive to animal life, as air holding no more than $\frac{1}{800}$ of the gas will cause the death of large animals. The medicinal properties of sulphurous mineral waters, such as those of Harrowgate, chiefly depend upon this gas. Many metals decompose HS., particularly if heated in it, and metals not oxidized by the air, as gold and silver, are tarnished at ordinary temperatures by the action of the HS., which exists in the atmosphere, being evolved by the decomposition of organic matter.

Bisulphuret of hydrogen ($HS_2.$), prepared by gently pouring a watery solution of bisulphuret of potassium into dilute muriatic acid; the potassium combines with the chlorine, and the hydrogen unites with the sulphur, forming chloride of potassium (K. Cl.) and bisulphuret of hydrogen ($HS_2.$), the latter falling to the bottom as a heavy, yellow fluid, insoluble in water, but rapidly decomposed by it unless free acid be present. $HS_2.$ is easily separated into HS. and solid sulphur.

SELENIUM (Se.),

DISCOVERED by Berzelius, and found in very small quantities in the native metallic sulphurets, existing as seleniurets of the same metals. It is a solid, of a dark brown colour, and when smooth has a metallic lustre. When burned in air it unites with oxygen, forming a colourless gas (oxide of selenium), remarkable for its pungent odour of horse-radish. When boiled with nitric acid it unites with two equivalents of oxygen, forming selenious acid. *Seleniuretted hydrogen* is formed by the action of acids upon metallic seleniurets. The sp. gr. of Se. is 4·32.

PHOSPHORUS (P.—*φως light, φερώ I bear*).

CHIEFLY found in animal organic matter, found also, in small quantity, in vegetables and minerals; it is manufactured on a large scale in London and Paris; in the latter city to the extent of 200,000lbs. annually. Phosphate of lime, which is the earthy constituent of bone, is the principal source of phosphorus. Bones are first burned to whiteness, then ground to powder, and to three parts of the powder are added thirty parts of water and two of oil of vitriol. The SO_3 unites with a portion of the lime of the bone-powder, and the remainder forms, with the whole of the phosphoric acid, a soluble salt which remains in the liquor when the insoluble sulphate of lime has been removed by straining. The strained liquor is evaporated to the consistence of a syrup, and being gradually mixed with about one-fourth of the weight of the bones, of powdered charcoal, the mass is dried at something below a red heat. It is reduced to powder, and placed in an earthen retort, in a furnace; a copper tube is adapted to the neck of the retort, one end of the tube dipping into the water of the bottle which serves as a receiver. The retort being gradually heated the excess of the phosphoric acid is decomposed by the charcoal, the carbon of which combines with the oxygen to form carbonic acid; the phosphorus, being free, passes over in the state of vapour into the copper tube, where it is condensed and falls in the liquid form below the surface of the water in the receiver. It is then melted under water and poured into glass tubes to solidify. Pure phosphorus is transparent and colourless, but the phosphorus of commerce is usually of a pale yellow or reddish colour; at ordinary temperatures it is soft, and may be bent or cut; at 32° it is brittle and crystalline in its fracture; it is insoluble in water; dissolves in the volatile oils, in ether, and in sulphuret of carbon; it melts at 108°, and boils at 550°, forming a colourless vapour; it is very inflammable, burning slowly at ordinary temperatures, emitting a light visible in the dark, and forming phosphorous acid, producing at the same time a penetrating and peculiar odour, somewhat like that of garlic. When heated to 120° phosphorus bursts into flame, and unites with the oxygen of the air to form phosphoric acid; it combines with oxygen in four proportions, and its equivalent is considered by Kane to be 31·4, which is double what it was formerly set down as being. Of its four combinations with oxygen the most interesting is phosphoric acid, which is procured by decomposing the acid solution of superphosphate of lime by carbonate of ammonia; phosphate of ammonia and carbonate of lime are formed; the former is evaporated to dryness and ignited, the ammonia is driven off, the phosphoric acid remains behind, and solidifies on cooling into a colourless glass, called *glacial* phosphoric acid. Phosphoric acid is formed also when phosphorus is burned under a bell-glass. This acid has a very strong affinity for water, and forms with it almost exclusively what are called monobasic, bibasic, and tribasic phosphates of water.

Phosphuretted hydrogen (PH_3.).—This gas may be formed by heating phosphorus in a solution of potash, or of barytes, or in milk of lime: the water being decomposed, gives its oxygen to one portion of the phosphorus to form hypophosphorous acid and hydrogen, to another forming phosphuretted hydrogen gas. If this gas, as it is evolved from the retort, be made to pass through the water of a pneumatic trough, each bubble as it bursts in the air takes fire and burns with a beautiful white flame, forming a ring of phosphoric acid vapour, which, widening as it ascends, will rise to a considerable height if the air of the apartment be still. The structure of this ring is very curious: it consists of a great number of small rings, which revolve rapidly on their axes, and whose plane is perpendicular to that of the general ring which they produce. This is called spontaneously combustible PH_3., to distinguish it from PH_3. prepared by heating hydrated phosphorous acid, as the latter, though producing similar phenomena, will not burn till set on fire.

Sulphuret of phosphorus is formed by fusing together equivalent weights of sulphur and phosphorus. This is the compound used in making phosphorous matches, and is much more inflammable than phosphorus.

CHLORINE (Cl.).

THE principal source of chlorine is common salt, which is a chloride of sodium, existing in large masses, called "rock-salt," and forming also the main saline ingredient in sea-water. Chlorine is found, but in small amount, in combination with calcium, mercury, lead, silver, and other metals. It is obtained in large quantities by decomposing with sulphuric acid a mixture of common salt and peroxide of manganese; half of the oxygen of the peroxide unites with the sodium, chlorine is expelled, and sulphates of soda and of protoxide of manganese are formed; in symbols thus: $Mn\ O_2. + Na\ Cl. + 2\ SO_3. = SO_3.\ Na\ O. + SO_3.\ Mn\ O. + Cl.$ About six parts of $Mn\ O_2$., eight of Na Cl., and thirteen of oil of vitriol, by weight, are employed; and as the manufacturers of chloride of lime generally make oil of vitriol, a proper quantity of acid of sp. gr. 1·600 is used in place of the strong oil of vitriol, and the expense of concentration is thus saved. Chlorine may be procured in small quantity by decomposing common muriatic acid, which is a solution of chloride of hydrogen in water, by peroxide of manganese, at a moderate heat; the hydrogen of the acid combines with the oxygen of the peroxide to form deuto-chloride of manganese, which, by a little increase of temperature, is resolved into proto-chloride and free chlorine. One part of $Mn O_2$. and three of H Cl. in a glass retort or flask, with a bent tube, will be sufficient to effect this object. The gas is rapidly absorbed by cold water, and combines with mercury, forming calomel; water at 90° must therefore be used.

Chlorine is a greenish yellow gas, hence its name (χλωρος *green*); it has a suffocating odour, and is very irritating when respired, even though largely diluted; its sp. gr. is 2·5. A lighted taper plunged into chlorine burns with a red smoky flame, which is soon quenched, though some bodies will burn in it better than in air or oxygen. Powdered antimony or arsenic thrown into a bottle of chlorine will burn with bright scintillations; tin and brass foil and phosphorus also burn spontaneously in it; a paper dipped in oil of turpentine takes fire in chlorine, the hydrogen burning, the carbon being deposited in the shape of thick black smoke. Cl. has a powerful affinity for hydrogen. The gases when mixed unite at ordinary temperatures, and with explosion if set on fire. This affinity for hydrogen gives to Cl. its property of decomposing organic substances. The property which Cl. possesses of depriving organic substances of their colour, or bleaching them, is that which is of most practical importance; if a little green grass be placed in a jar of Cl., it will be deprived of its colour in a very short time. The prevailing opinion was, that water was necessary for this purpose, and that the Cl. combined with the hydrogen, whilst the oxygen formed with the organic substance a new colourless compound. Dr. Kane, however, has shown that this is not the case, "but that the Cl.

enters into the constitution of the new substance formed, sometimes replacing hydrogen, at others simply combining with the coloured body, and in some the re-action being so complex, that its immediate stages cannot be completely traced." Cl. is employed as a disinfectant, owing to its affinity for hydrogen. For this purpose it should be evolved slowly, which may be managed by placing some chloride of lime in a cup, with means attached for dropping in dilute sulphuric acid; sulphate of lime is formed, and Cl. set free.

Water holding Cl. in solution possesses the colour, odour, taste, and bleaching qualities of the gas; when this water is exposed to the sun's rays, it is decomposed gradually, chloride of hydrogen being formed, and oxygen set free; the fluid loses its bleaching properties and colour, and acquires an acid taste and action (muriatic acid).

Cl. in contact with water at 32° forms a hydrate, which crystalizes in plates, and is decomposed at 45°. If some of these crystals be inclosed in a strong glass tube, the Cl. when set free exerts a pressure sufficient to condense itself into a fluid. This phenomenon afforded the first instance of the liquefaction of a gas.

Cl. forms numerous combinations: it unites with nearly all the simple substances, and in most instances forms more than one compound with each.

Cl. may be recognised by its odour, colour, bleaching properties, and by producing with a solution of nitrate of silver a white curdy precipitate, insoluble in acids, soluble in water of ammonia, and which becomes blackened when exposed to the sun's rays.

Hypochlorous acid (Cl. O.). — By shaking some red oxide of mercury, diffused in a little water, in a bottle containing Cl., the gas is rapidly absorbed, and chloride of mercury and hypochlorous acid are formed. The solution of Cl. O. is yellow, its odour is like that of Cl.; it bleaches powerfully, oxidizes most bodies with great energy, and decomposes spontaneously, forming chloric acid and chlorine. Cl. O. unites with bases to form salts, which are called hypochlorites, and possess the bleaching powers of the acid to a great extent.

Chloric acid (Cl. O_5.).—Cl. brought into contact with an alkaline solution is rapidly absorbed, and the liquor acquires bleaching qualities. Chemists are undecided as to the precise nature of the re-action in this case. One theory is, that Cl. unites directly with the alkali, forming, if potash be used, chloride of potash; another holds, that a quantity of alkali may be decomposed, as actually occurs with oxide of mercury, and that chloride of potassium and hypochlorite of potash may exist in the liquor. This last is the theory generally adopted. The bleaching alkaline liquor is decomposed by boiling, oxygen gas being evolved largely, whilst chloride of potassium and chlorate of potash are formed. The chlorate of potash of commerce is procured in this way. A solution of the acid is prepared by acting upon a solution of chlorate of barytes with SO_3. In its strongest form it is a thick oily fluid, sets fire to many organic substances, is a powerful oxidizing agent, but does not bleach, nor precipitate a solution of nitrate of silver. The compounds of Cl. O_5. yield, when heated, a metallic chloride and oxygen; when mixed with sulphur, and rubbed in a warm mortar, they explode; and if thrown upon an ignited coal, deflagrate. The chlorate of potash is extensively used in making matches. Cl. O_5. is composed of one equivalent of Cl. and five of oxygen.

Chlorous acid (Cl. O_4.).—If chlorate of potash in fine powder be acted upon by sulphuric acid, it will be decomposed, and the chloric acid, when given off, will form two compounds; one chlorous acid, containing four atoms of oxygen, the other perchloric acid, having seven atoms of oxygen. Cl. O_4. may be collected over mercury, or in a dry jar. The process must be conducted with great caution. Cl. O_4. is a yellowish green gas, and has an aromatic odour; it is rapidly absorbed by water, bleaches, is a powerful oxidizing agent, and is very easily decomposed; heated above 212° it explodes, and phosphorus takes fire and burns in it with brilliancy; with bases it forms salts, called chlorites.

Perchloric acid ($Cl. O_{7.}$), obtained by washing the saline residue of the lastmentioned process in cold water. The bisulphate of potash dissolves, leaving perchlorate of potash, which is sparingly soluble in cold water: this perchlorate may then be dissolved in boiling water, from which it crystalizes upon cooling. $Cl. O_{7.}$ may be procured by mixing this salt with half the weight of oil of vitriol and as much of water, and distilling; the acid comes over with the water; if an excess of oil of vitriol be used, the $Cl. O_{7.}$ may be obtained free from water, in the shape of a white crystaline mass, which is very deliquescent, and evolves much heat when mixed with water. $Cl. O_{7.}$ is not altered by muriatic acid or alcohol, and is the most permanent compound of Cl. and oxygen: it has no spontaneous action on organic bodies, and its potash salt is so very sparingly soluble, that $Cl. O_{7.}$ has been used to detect potash.

The oxidizing action of these compounds of Cl. is produced by absorption of their oxygen by the oxidized body, Cl. being liberated.

MURIATIC OR HYDROCHLORIC ACID (HCl.).

THIS substance has been long known under the names of spirit of salt, marine acid, muriatic acid, and hydrochloric acid; it is in strict chemical phrase, a chloride of hydrogen. Gaseous HCl. is prepared by distilling from a retort, connected with a mercurial pneumatic trough, some common spirit of salt; the gas passes over also when common salt is acted upon by oil of vitriol; water being decomposed, its oxygen unites with the sodium forming soda, which combines with the $SO_{3.}$ forming sulphate of soda, and its hydrogen unites with chlorine to form HCl. A mixture of equal volumes of chlorine and hydrogen will combine to form HCl. when exposed to the light. In nearly all cases of the action of chlorine on organic matter, HCl. is formed.

HCl. is a colourless, invisible gas; when dry it has no action upon vegetable colours, but if moisture be present it reddens litmus, and restores the colour of turmeric paper browned by an alkali; mixed with damp air it forms heavy white fumes, consisting of liquid acid, condensed in minute drops; it may be liquified by great pressure: it is irrespirable, but does not produce the suffocating effects of chlorine. If HCl. gas be brought into contact with a metallic oxide, a metallic chloride and water are formed; if any of the more oxidable metals, such as iron, zinc, or potassium, be heated in a current of the gas, it is decomposed, and a metallic chloride being formed, hydrogen is evolved. HCl. has a very strong affinity for water: if a jar of the gas be opened, under water, the fluid will rush in, and by combining with the gas will occupy the jar. Liquid HCl. is prepared by acting upon chloride of sodium with an equal weight of sulphuric acid, and the same of water. The dilute acid is gradually introduced by a funnel, and the gas passes over into the first of a range of three necked bottles, half-filled with water: the water of the first bottle being saturated with the gas, the latter passes over into the next, and so on, until all are saturated. A vertical safety-tube is placed in each bottle, so as to prevent the water of the second bottle rushing back through the connecting-tube into the first, by restoring the equilibrium of pressure, in case any sudden condensation occurred in the first bottle. Pure HCl. may be more readily prepared for chemical uses by redistilling the muriatic acid of commerce.

The manufacture of this acid on a large scale, is more for the purpose of extracting the soda from the sulphate of soda left after distillation, than to obtain the acid; the difficulty in a soda factory being how to get rid of the HCl. produced. When the object is to procure the acid, the same form of apparatus is used as that employed for the manufacture of nitric acid; each cylinder being made to hold from four to five cwts. of common salt. The strongest acid prepared in this way has a sp. gr. of 1·211. To obtain water fully saturated with the gas, it must be kept near the freezing point by artificial cold, when it absorbs 480 times its volume, and increases in bulk one-fifth.

Common muriatic acid often contains SO_3, always a trace of iron derived from the cylinders in which it is made, and sometimes sulphurous acid. These may be detected by adding to some of the dilute acid, nitrate of barytes, which will throw down a white precipitate if sulphuric acid be present, yellow prussiate of potash which gives a blue precipitate if iron exist in the compound, and solution of proto-chloride of tin which throws down brown sulphuret of tin if sulphurous acid be present. The HCl. gas may be recognised by its action on moist litmus paper, by fuming in the air, and by forming with ammonia dense white clouds of sal-ammoniac; the fluid acid is detected by giving with nitrate of silver a curdy white precipitate, not soluble in nitric acid, but soluble in water of ammonia, and which is blackened by exposure to light.

Nitro-muriatic acid, called *aqua regia* from its power of dissolving gold, which was considered the king of metals (*rex metallorum*), is formed by the mixture of nitric and muriatic acids. The fluid colourless acids when mixed assume a yellow colour, and a strong odour of chlorine and nitrous acid is perceptible; there are formed in this case chlorine, nitrous acid, and water. The decomposition only proceeds so far as to saturate the liquid with chlorine, as, if a metal be placed in the fluid, the chlorine unites with it, and new quantities of acid are decomposed. Holding Cl. in a highly concentrated state, this fluid is employed to dissolve gold and platina, which are not soluble in nitric acid, and it is used also to oxidize bodies which are not oxidable by nitric acid.

Chloride of sulphur (S_2. Cl.), obtained by conducting a current of chlorine into a tubulated retort containing some sulphur. The Cl. and sulphur unite to form a volatile reddish yellow liquid, which distils over, and is condensed in a cooled receiver. S. Cl. when exposed to the air gives off very acrid fumes. It consists of two atoms of sulphur, and one of Cl.

Chlorides of phosphorus.—Cl. unites with P. in two proportions, forming a liquid proto-chloride, and a solid perchloride.

IODINE (I.).

SEA-WATER is the principal source of iodine: it is found combined with sodium and magnesium. In the mineral kingdom it is found united with silver. It is extracted for commercial purposes from *kelp*, which is the mass of ashes remaining after the burning of various species of sea-weed. Kelp is diffused through water, to which it yields about half its weight of salts; the solution is then evaporated in an open pan, and at a certain point of concentration begins to deposit muriate, carbonate, and sulphate of soda, which are removed from the boiling liquor; the fluid is then poured into a shallow pan, and upon cooling deposits a crop of crystals of chloride of potassium. These operations are repeated till no more crystals form, and a heavy dark-coloured liquid remains, which contains iodine combined with sodium, mixed with a large amount of other salts. To this liquid oil of vitriol is added in sufficient quantity to make it very sour, which causes an evolution of carbonic acid, sulphuretted hydrogen, and sulphurous acid gases, and a deposition of sulphur. After standing a couple of days, the fluid is heated with the peroxide of manganese to separate the iodine. The process is conducted in a leaden retort, adapted to a series of bottles. At a temperature of about 140° the iodine begins to come off, and is condensed in the bottles; manganese and sulphuric acid are added as the process goes on, until no more iodine can be extracted from the fluid. In this operation the peroxide is in contact with hydriodic, hydrochloric, and sulphuric acids; but the SO_2. must be in sufficient quantity to decompose the iodides only, as, if chlorine and iodine were evolved together, chloride of iodine would be formed, whereas in the successful process, the metal of the iodide is oxidized by the oxide of manganese, and iodine is set free.

Iodine may also be procured by adding to the liquid containing iodide of sodium a solution of sulphate of copper, in which the copper is converted into a sub-oxide by the addition of proto-sulphate of iron. Sulphate of soda and a pale yellow sub-iodide of copper, insoluble in water, are formed; this last is decomposed by peroxide of manganese and SO_8., as in the former process, and the various crystalizations are avoided.

Iodine usually exists in small scales of a bluish black colour and metallic lustre; it may be obtained from solution in oblique octohedral crystals, with a rhombic base, or in prisms; its sp. gr. is 4·948; it fuses at 225°, and boils at 347, evaporates at ordinary temperatures, and more rapidly when moist than when dry; it imparts a yellow stain to the skin, which is not permanent; its vapour is of a beautiful violet colour, hence the name iodine (*ιοειδης violet-coloured*), and is the heaviest of gaseous bodies. Iodine dissolves in alcohol and ether, forming reddish brown solutions; it is also soluble in solutions of iodides; pure water dissolves about $\frac{1}{7000}$ of its weight of iodine, and is tinged of a brownish colour by it. The chemical combinations of iodine are generally analogous to those of chlorine, but its affinities are not so strong. Iodine forms with solution of starch an insoluble compound of a dark-blue colour, which serves as a very delicate test for the detection of iodine. To apply this test iodine must be free; for, if it exist as an iodide in solution, no blue colour will be apparent till chlorine be added to liberate the iodine; this blue colour disappears upon adding chlorine in excess, chloride of iodine being formed; and also upon the application of heat, but returns when the solution is cooled. Soluble iodides form with nitrate of silver an iodide of silver of a pale yellow colour, insoluble in ammonia; with salts of lead an iodide of a rich yellow colour, and with bichloride of mercury (corrosive sublimate) a fine scarlet iodide. Iodine combines with most of the non-metallic bodies, and with all the metals; it combines with oxygen in three proportions, forming *iodous, iodic*, and *periodic* acids; the iodic acid forms, with bases, salts called iodates, which are analogous to chlorates, and when heated are resolved into oxygen and a metallic iodide. Upon this principle is conducted one process for the manufacture of iodide of potassium. Iodine is dissolved in a solution of potash, and evaporated to dryness; iodide of potassium and iodate of potash are formed; upon fusing the mass oxygen is given off abundantly from the iodate, and pure iodide of potassium remains. Iodic acid is composed of one atom of iodine and five of oxygen.

Hydriodic acid.—This, the only compound of iodine and hydrogen, is procured, as a colourless gas, by the reaction of iodine, phosphorus, and water. To obtain it in solution in water, iodine is acted upon, diffused through water, by sulphuretted hydrogen gas: the iodine combines with hydrogen, and sulphur is set free.

BROMINE.

THIS element is found generally combined with sodium or with magnesium, in sea-water, in many species of sea-weed, and in certain springs. Through the mother liquor, called *bittern*, which remains after common salt has crystalized out of sea-water, chlorine is passed, and the liquor is tinged of a yellow colour by the liberated bromine; by shaking this liquor with some ether, the bromine is taken up, an ethereal solution of bromine of a hyacinth red colour, being produced; by acting upon this with potash a mixture of bromide of potassium and bromate of potash are formed, which, upon fusion, give off oxygen, leaving pure bromide of potassium; by treating this with SO_3 and peroxide of manganese bromine is given off, and may be distilled into water, in which it sinks to the bottom.

Bromine solidifies at a temperature of 4°; is deep red by transmitted, and black by reflected, light; its sp. gr. is 2·97; it is called bromine from its heavy, disagreeable odour (βρωμος, *a stench*); it gives off copious orange-red fumes, and must be preserved under water, in which it is sparingly dissolved: it is taken up by alcohol as as well as ether; a lighted taper burns in it, for a moment or two, with a green flame and much smoke; some metals in fine powder take fire in its vapour; it bleaches vegetable colours, leaving a yellowish stain itself, and is poisonous. Bromine may be detected by its colour and odour, and by bromine, or metallic bromides, giving, with solution of nitrate of silver, a curdy-white precipitate, insoluble in nitric acid, but soluble in ammonia, and which may be distinguished from the chloride of silver by giving vapours of bromine when heated with chlorine-water.

Bromine unites with five atoms of oxygen to form bromic acid, and with hydrogen to form hydrobromic acid; this last is obtained on the same principle as hydriodic acid, and bears a close analogy to muriatic acid in its chemical relations, but may be easily distinguished by evolving bromine in contact with Cl. or NO_5. There are bromides of sulphur, phosphorus, and iodine.

FLUORINE (F.).

THIS substance has not yet been obtained in a state of isolation, for so intense and varied are its affinities, that immediately it is freed from one compound it enters into combination with another body. The only substances upon which it is incapable of acting are those already saturated with it, such as fluoride of calcium (fluor spar). The most ingenious experiments upon fluorine have been those of the Messrs. Knox, conducted in apparatus made of fluor spar; but, even in this case, the isolation of fluorine was not demonstrated to a certainty.

Hydrofluoric acid, or fluoride of hydrogen (HF.), is the most important compound of fluorine. It is prepared by distilling fluor spar in powder with twice its weight of the strongest oil of vitriol from a leaden retort into a leaden receiver kept cool by ice; sulphate of lime and hydrofluoric acid are formed, the latter distilling over as an acid liquor of a very suffocating odour, and excessively corrosive. It is heavier than water, increasing in weight by dilution to a certain extent; very volatile, and boils at 60°; it acts rapidly upon the metals, except gold, platina, silver, and lead, forming metallic fluorides with evolution of hydrogen. HF. corrodes and dissolves glass, forming fluoride of silicon with the silica of the glass; upon this principle designs may be etched upon glass. This process may be effected by using either the liquid acid or the gaseous. The glass-plate must be covered with a coating of wax, and the drawing or design being traced with a sharp-pointed tool lays bare the surface to be acted upon; the liquid acid, being poured over the plate, will corrode such parts of the glass as are not protected from its action by the wax. In applying the gaseous acid the same plan is adopted, save that the plate is placed over a leaden dish, holding powdered fluor spar and oil of vitriol, which, when heated, give off the acid vapours. The etching in the last case has a rough appearance; this is occasioned by the ascent of watery vapour with the gaseous acid in sufficient quantity to decompose the fluoride of silicon, and silica being formed is deposited upon the glass.

SILICON (Si.).

THIS is the most extensively distributed of the simple elements, being estimated to constitute one-sixth of the entire mass of the mineral crust of the globe. It always exists in combination with oxygen, forming *silicic acid*, popularly called *silica*. Flints, quartz, agate, and sand, are silica, more or less pure, which, in combination with metallic oxides, form silicates — a very large class, including most of the earthy minerals. It is very difficult to obtain silicon in a state of purity; it is prepared by acting upon the double fluoride of silicon and potassium with pure potassium, in an iron cylinder, or in a tube of hard glass. Silicon so obtained is a dull brown powder, and takes fire when heated in air or oxygen, forming silicic acid.

SILICA ($Si\ O_3$.)

EXISTS in very hard masses, in a state of purity, constituting quartz rock. To reduce it to powder, it must be heated to redness, and then thrown into cold water, or it may be more minutely divided by fusing, in a platina crucible, equal parts of carbonates of potash and soda, and adding powdered flint in small portions at a time; the silica dissolves in the melted alkali and carbonic acid is given off; if a stronger acid be added to these alkaline silicates dissolved in water, silicic acid will be thrown down in the shape of a gelatinous hydrate, which forms a white, somewhat gritty, powder when dried. Silica has a sp. gr. of 2·66; it is fusible only in the flame of the oxyhydrogen blowpipe, in which it forms a colourless glass. Many mineral waters contain silica in solution, which being precipitated in the substance of organic matter, produces silicious petrifactions, in which the tissues of the substance are preserved with the utmost accuracy. It is probable that much of the silica existing in nature has been deposited in the soluble state. Silica is of great importance in the arts, being a constituent of glass, porcelain, and all kinds of delf and earthenware. Hydrofluoric acid is the only acid which can dissolve silica. It is composed of one atom of silicon and three of oxygen; it does not combine with hydrogen nor nitrogen, but forms with chlorine *chloride of silicon*, and with fluorine *fluoride of silicon* and *hydrofluosilicic acid*.

BORON (B.),

ORIGINALLY obtained by decomposing boracic acid by galvanic agency. It may be prepared by acting upon fluoborate of potash with potassium. This salt is composed of fluoride of boron united to fluoride of potassium. In the decomposition with potassium all the fluorine goes to the potassium, and boron is liberated. Boron is a dark olive substance, insoluble in water; it takes fire when heated to 600° in air or oxygen; and forms boracic acid by igniting it with carbonate, or with nitrate of potash; or, by boiling it in nitric acid, the same result is produced. It is not an abundant element in nature, and is found in combination only with oxygen, forming boracic acid. Borate of soda is found in certain Indian springs, and when crystalized in a rough way is known in commerce by the name of *tinkal*, or crude borax. Boracic acid is found free, or in combination with a small quantity of ammonia in the volcanic lakes of Tuscany; the watery vapour also which escapes there from fissures in the earth contains it along with muriatic acid. The water of these lakes, when evaporated, affords crystals of boracic acid, in which state it is exported for the manufacture of borate of soda (borax). Boracic acid, the only compound of boron and oxygen, may be obtained pure by boiling the native acid with eight parts of water and a little white of egg, and then filtering. On cooling the acid crystalizes, in an irregular form, in large brilliant plates, which feel soft and unctuous. It may be procured, also, by dissolving borax in four times its weight of boiling water, and adding SO_3. till the liquor becomes sour; the acid crystalizes on cooling; but a second solution and crystalization are necessary to free it from any sulphuric acid, or sulphate of soda, that may attach to it. Boracic acid may be recognised by its solution in alcohol, burning with a beautiful green flame;

it exerts very feeble affinities, all its salts being decomposed by the weakest acids, and many of them having an alkaline reaction; it does not quite redden litmus paper, merely giving it a port-wine colour, and a strong solution of it has an alkaline reaction on turmeric paper. It consists of one atom of boron and three of oxygen, and forms compounds with chlorine, fluorine, sulphur, and selenium, but not with hydrogen or nitrogen.

CARBON (C.).

THIS element is found in great abundance in vegetable and animal substances; it is also a large constituent in the mineral kingdom. In the last case, it may be presumed to have an organic origin. Thus coal has been formed by the aggregation of large masses of wood, derived from the forests which covered the earth in one of its earlier conditions. Suffering immense pressure from the superposited layers of mud and sand, this wood has undergone decomposition, during which, as in the formation of peat at the present time, carbonic acid was evolved in large quantities. In the case of the native carbonates also, an organic derivation may be demonstrated, for the largest masses of carbonate of lime are merely aggregations of the shells of animals; the organic characters, in some instances, being more or less removed by fusion from proximity to igneous rocks, or by the solvent power of water holding carbonic acid, which passing through strata of shells, will have taken up the carbonate of lime and subsequently deposited it in a crystaline shape. The other native carbonates may have been the result of double decomposition, as water holding carbonate of lime in solution will form sulphate of lime, if it percolate through a stratum of oxidized iron pyrites, and carbonate of iron will be generated.

Carbon is found in a great variety of forms. In a state of purity and of crystaline aggregation it constitutes the diamond, found in alluvial strata of certain districts in Asia and South America; the diamond crystal usually presents a great number of sides, bounded by curved edges, by which it has the property of splitting glass like a wedge, and not of scratching it like a file; the crystals are mostly hemihedral, and often rough and discoloured at the surface; they all cleave parallel to the faces of a regular octohedron (fig. 6, page 12), but its properties in relation to light are peculiar, and distinguish it from mineral crystals of the regular system: its structure has been found to consist of layers, sometimes having cavities indicating that the crystal has been soft, and has concreted gradually; it has also been recently discovered, that the diamond when burned leaves behind a minute skeleton of inorganic matter, upon which it may be supposed the organic element of which the diamond is formed was originally deposited.

The diamond is the hardest of known bodies; it cuts every other, and can be ground only by its own powder; it is generally colourless, sometimes brown or rose-coloured; its brilliancy is owing to its great refractive power; it is a bad conductor of heat and electricity, resists the action of most chemical agents, but burns brilliantly in melted nitre, forming carbonate of potash; it burns also when heated to redness in oxygen gas; its sp. gr. is about 3·5.

Plumbago or *graphite* is a remarkable form of carbon; it is found in many places, the purest in Borrodale, Cumberland; it is opaque, crystalizes in rhombohedrons or six-sided tables, but its general form is that of brilliant leaves or spangles; it is soft and unctuous to the touch, and leaves upon paper a continuous dark gray streak, hence its use in the manufacture of black-lead pencils: it is found only in igneous rocks, such as granite and mica slate, and contains generally a large admixture of iron in the metallic state, for which reason it was once regarded as a carburet of iron; its origin appears to have been connected with iron, and a very high temperature for the reasons just stated, and also because it may be formed by adding charcoal to fused cast-iron; upon cooling, the charcoal will be found to have formed flexible plates more or less six-sided; its sp. gr. is 2·5; it is a better conductor of heat and electricity than diamond, but it is difficult to set on fire.

Carbon, more or less pure, may be obtained by raising organic matter, vegetable or animal, to a very high temperature in close vessels; carbon so procured differs in appearance very much, according to the substance from which it is formed, &c. *Coke* is carbon mixed with the earthy material of coal; *anthracite* is carbon nearly pure, and has been formed by the proximity of coal to igneous rocks, by the heat of which its volatile materials have been driven off. These substances, though difficult to ignite, evolve intense heat during their combustion. When an organic substance which contains carbon and hydrogen is set on fire, with free access of air, it is converted into water and carbonic acid; but if the supply of air be limited, no carbon is consumed until the hydrogen is all expelled and forms water. Wood-charcoal and lamp-black are manufactured upon this principle. Large quantities of charcoal are obtained in the manufacture of vinegar from the destructive distillation of wood. The more slowly the charring process is conducted, the larger will be the amount of charcoal.

Animal charcoal is the result of decomposition of animal matter in close vessels: it is called in the arts *bone black* or *ivory black*, bone being the principal material from which it is derived. In this state it is mixed with phosphate of lime, the earthy constituent of bones.

The inflammability of carbon varies with its state of aggregation; it is least in graphite, and so great in wood-charcoal slowly prepared and reduced to powder, that it will sometimes inflame spontaneously, and thus give occasion to such accidents as occur in powder-mills. Carbon has a strong tendency to unite with colouring and odorous matter; animal charcoal, owing to the minute division of its particles, has this property in a remarkable degree. In the purification of sugar, and in clearing many organic solutions, this property is applied; barrels intended to hold water for any length of time are charred internally, in order to remove putrefactive organic matter from their contents. Charcoal possesses the power of absorbing gases to a considerable extent; a piece of wood-charcoal will absorb 90 times its volume of ammoniacal gas. The gases so absorbed undergo no chemical change; they are retained between the pores of the charcoal by a powerful cohesive attraction. The sp. gr. of carbon is undecided; it is assumed by one eminent chemist to be 843.

Carbon combines with oxygen in several proportions. The most important of these combinations, are *carbonic oxide*, and the *carbonic* and *oxalic* acids.

Carbonic acid is found in the atmosphere; and, in combination with metallic oxides, it forms the numerous class of carbonates: it is produced during the slow combustion of most vegetable bodies, and in volcanic districts is evolved in large quantities from the earth: it is formed along with alcohol in the fermentation of sugar. For the purpose of experiment it may be procured by acting upon carbonate of lime with any stronger acid; the muriatic is generally used, owing to the solubility of the products. Pieces of white marble are placed in a wide-necked bottle, and the acid, diluted with its own bulk of water, is poured upon them by means of a funnel; the acid is evolved, and may be collected in dry jars, which are known to be full when a lighted taper, placed near the mouth of the jar, is extinguished. In this case the hydrogen of the muriatic acid ($HCl.$) unites with the oxygen of the oxide of calcium ($Ca\ O.$) to form water ($H\ O.$), and the chlorine forms with the calcium chloride of calcium ($Ca\ Cl.$), carbonic acid ($C\ O_2.$) being liberated.

CO_2. is a colourless, invisible, and irrespirable gas; it acts as a narcotic poison on the animal system; for even diluted in the proportion of one part of the gas to ten of air, it will gradually produce stupor and death if inspired; it is heavy, its sp. gr. being 1·521, and when evolved will accumulate; hence the cause of death in lime-kilns, dry wells, and large vats. In all cases where the gas is liable to be evolved and accumulated accidents may be avoided by observing if a lighted candle be extinguished in the suspected atmosphere; CO_2. not being a supporter of combustion, will, if present, at once quench the flame. The lower stratum of air of certain caverns in volcanic districts is contaminated with this gas, and dogs are asphyxiated in it for the amusement of visitors, whilst the upper air of the cavern is respired with impunity; the dogs in such cases are revived by being thrown into cold water. Water dissolves its own bulk of CO_2. gas, the solution having an agreeable acidulous taste, and sparkling when agitated; it imparts to blue litmus paper a wine-red colour, which disappears on exposure to air or heat. Water may be made to absorb a much larger amount of CO_2. by means of pressure, the gas escaping with effervescence when the pressure is removed. Upon this principle many effervescing fluids are manufactured, as refreshing beverages, to remove thirst, or to allay the irritation of the mucous membrane of the stomach, which often follows the use of an undue quantity of spirituous potations. The latter effect is produced by the sedative influence of the carbonic acid gas.

CO_2. may be liquified by a pressure of thirty-six atmospheres, and forms a colourless and excessively volatile fluid. If the pressure be suddenly removed this fluid will be converted into gas with such rapidity, that a portion of it will be solidified by the sudden abstraction of the heat necessary to vaporize the other portion. Solid CO_2. procured in this way is a white filamentous mass; it evaporates slowly, and is very soluble in alcohol and ether; the evaporation of the ethereal solution produces the most intense cold known, being estimated at 180° below zero of Farenheit. The existence of carbon in CO_2. may be demonstrated by heating to redness a piece of potassium in a current of the gas; the metal burns with a bright violet flame, forming potash by uniting with oxygen, whilst the carbon is deposited in the shape of a brilliant jet-black film.

CO_2. combines with bases to form the class of salts called carbonates ; these are neutral, basic, or acid salts, according to the proportions of base and acid—being equal in the first, the base preponderating in the second, and the acid in the third ; all carbonates are recognised by yielding CO_2. when acted upon in the cold by muriatic acid.

Carbonate of potash is obtained by the incineration of plants which have not grown in, or on, the brink of the sea ; in these potash is contained in combination with various acids, as nitric, malic, oxalic, acetic, which are converted into carbonates by combustion : the softer and more succulent plants yield the most potash ; and the composite and cruciferous families afford it in greatest quantity. Of woods, the leaves yield more than the small branches, and these more than the stems. In America and Russia, where large forests exist, the smaller timber is burned, and the ashes, being collected, are boiled in large pots—hence the name *pot-ashes*. The soluble salts are separated from the insoluble by this means, and carbonate of soda is obtained in a pure form by evaporating to dryness ; this constitutes the *pearl-ashes* of commerce, of which the American samples contain about 85 per cent of carbonate of potash, the Russian about sixty per cent., the remainder being composed of silica, sulphate of potash, and chloride of potassium. Carbonate of potash is generally prepared for chemical purposes by roasting bitartrate of potash (cream of tartar) ; the tartar is converted by the heat into carbonic acid, which unites with the potash ; this is digested with water, and, having been filtered to separate charcoal, is evaporated to dryness. The white granular mass which is formed has long been known under the name of *salt of tartar ;* it is a deliquescent, very soluble salt, and has a strong alkaline reaction. By passing a current of carbonic acid gas through a solution of this salt at a temperature not above 100°, *bicarbonate* of potash is formed; it is a much less soluble salt, but is converted into neutral carbonate when its solution is boiled.

Carbonate of soda is manufactured on a large scale from common salt, which has first been converted into sulphate of soda; this sulphate, freed from water, is mixed with lime and small coal, and, being exposed to a strong heat in a furnace, the whole forms a mass called *black ash*, from which, after a protracted process, pure carbonate of soda is procured. This salt crystalizes in flat, oblique, rhomboidal prisms, which contain two equivalents of water; in a dry atmosphere all this water is lost. $Na\ CO_2. + 10\ HO.$ dissolves in five parts of cold, and in less than one of boiling water; it is fused in its own water of crystalization; the dry carbonate which remains after the water has evaporated is called *soda siccata* (dried soda). Carbonate of soda was formerly obtained from the ashes of salsola soda and of other marine plants; the mass of ashes was called *kelp* and *barilla*, and was imported from the coasts of France and Spain, and also from the western coast of Ireland, and from the Orkneys. *Bicarbonate of soda* is formed by passing a stream of $CO_2.$ through a solution of the carbonate. *Sesquicarbonate* is found on the banks of certain lakes in Northern Africa, whence it is imported under the name of *trona:* it consists of two proportions of carbonate of soda, three of carbonic acid, and four of water. *Carbonate of barytes* is found native, and has been used in the manufacture of glass.

Carbonate of lime.—This body exists abundantly under the denominations of lime-stone, marble, &c.; it may be obtained pure by decomposing chloride of calcium with carbonate of ammonia. Muriate of ammonia and carbonate of lime are formed, the latter insoluble in pure water, but soluble in water holding carbonic acid in solution, not from the formation of soluble bicarbonate of lime, but owing to a solvent property existing in the water itself. When such a solution is heated or exposed to the air for some time the carbonic acid is evolved, and the carbonate of lime is deposited as an incrustation; hence the formation of stalactites, &c.

Carbonate of magnesia is found native in rhomboidal crystals; it may be formed by dissolving magnesia in water of carbonic acid, from which it will crystalize in six-sided or eight-sided prisms; this salt is decomposed by hot water, carbonic acid passing off, and the common carbonate of magnesia remaining. This carbonate is prepared by mixing boiling solutions of sulphate of magnesia and carbonate of soda, the first being slightly in excess. This carbonate is very light, nearly insoluble in water, and is composed of carbonate and hydrate of magnesia.

Protocarbonate of iron is found native; it may be prepared by decomposing protosulphate of iron with carbonate of soda: a white precipitate is formed, which, on exposure to air, absorbs oxygen and gives off carbonic acid, becomes green, and ultimately red, being converted into peroxide of iron. Protosulphate of iron exists in chalybeate springs, being soluble in water containing carbonic acid.

A carbonate of zinc may be formed, and carbonates of copper exist native; one of these is known by the name of *malachite*, and is used as a paint; it is of a bright green colour.

Carbonate of lead ($PbO. CO_2$.) found native, and may be obtained in a fine crystaline powder by decomposing a solution of nitrate of lead, with carbonate of soda. The *white lead*, or *ceruse* of commerce, consists of a number of basic carbonates, mixed in uncertain proportions. White lead is manufactured by exposing thin sheets of metallic lead to the fumes arising from vessels containing weak vinegar, which are kept warm by being placed in fermenting tan; the lead forms an oxide with the oxygen of the air, which combines with the acetic acid of the vinegar fumes, forming a basic acetate of lead, which is decomposed by the carbonic acid of the air, by which basic carbonate and neutral acetate are formed; this last under the influence of the air takes up a fresh quantity of lead and the decomposition is repeated, a very small portion of acetic acid being necessary to produce a large amount of ceruse. This process has been recently modified and improved by exposing finely-powdered protoxide of lead (litharge), mixed with one per cent. of acetate of lead, to a stream of carbonic acid, generally obtained from the fermenting vats of a brewery.

Carbonic oxide (CO.) is formed when CO_2. is passed through a tube containing red-hot charcoal, another atom of carbon being taken into combination. It is a colourless, inodorous gas; does not affect vegetable colours; extinguishes a taper; but burns itself with a pale blue flame, forming CO_2.

Oxalic acid ($C_2\ O_3$.). This acid is found in combination with potash in plants of the rumex kind, forming *salt of sorrel;* it is also found united with lime in rhubarb-root, and in many lichens: it was formerly manufactured, for the most part, from the *oxalis acetosella.* It is generally a result of the action of nitric acid upon vegetable substances, and its manufacture is based upon this principle. A quantity of sugar or starch is placed in an earthen pipkin, of which a great many are arranged in a shallow vessel holding warm water, and about four parts of NO_5. of sp. gr. 1·42, are poured into each pipkin; the sugar, or starch, is oxidized, nitrous fumes escaping, after a little time one part more of acid is added, and the temperature increased; the contents of the various pipkins are mixed, evaporated to a pellicle, and set aside to crystalize; the crystals are purified by repeated solution and crystalization. The object effected by this process is the removal of hydrogen from the vegetable substance acted upon, and the substitution of oxygen in its stead. Oxalic acid presents itself in oblique rhombic prisms, which contain three atoms of water, one being basic, that is to say, chemically united to the acid, and remaining after two atoms are driven off by heat. CO_3. is converted into CO_2. by contact with peroxide of manganese and other peroxides; it is also converted into CO_2. by excess of nitric acid or chlorine.

The oxalic is an intense acid; one grain of it in 30,000 grains of water will affect litmus paper; it leaves no charcoal residue when acted upon by heat; it throws down with lime water a precipitate insoluble in excess of oxalic acid, or in any vegetable acid; it has a strong poisonous action, for which magnesia is the best antidote; chalk and lime are also used for the purpose. There are three oxalates of potash,—the neutral *oxalate*, the *binoxalate* (salt of sorrel), and the *quadroxalate;* the two latter are called in commerce *salt of lemons*, and are used for removing iron moulds and stains of ink, which they effect by forming a soluble double salt with peroxide of iron. *Oxalate of lime*, found in rhubarb and in many of the lichen family, may be prepared by decomposing oxalate of ammonia with a soluble salt of lime; it is soluble in mineral, but not in vegetable acids, or in water. *Oxalate of silver* is interesting from its being resolved into carbonic acid and metallic silver on the application of a moderate heat. There are many double oxalates, such as oxalate of copper and potash.

Chlorocarbonic acid is formed by the exposure to light for some hours of a mixture of equal volumes of chlorine and carbonic oxide; it was called *phosgene gas* by Sir H. Davy, who discovered it; by contact of water it is resolved into carbonic and muriatic acids.

There are several combinations of carbon and oxygen, which, though interesting to a certain extent, cannot be fully noticed here; these are *rhodizonic acid* (C_7. O_{10}. + H_3.), *croconic acid* (C_5. O_4.), *mellitic acid* (C_4. O_3.), which is found native, combined with alumina in *honeystone*, or *mellite*. Carbon forms with sulphur a sulphuret of carbon (CS_2.) and with chlorine four different chlorides of carbon.

THE METALS.

There are forty-two metals, all possessing general properties by which they are readily recognised; their lustre is almost peculiar, and is called, therefore, metallic; they are good conductors of heat and electricity: in this respect the worst metallic conductor is better than the best of the non-metallic bodies. In colour and density great difference exists amongst the metals. Silver is white, gold yellow, copper red, but the majority are of a bluish grey; platina is twenty-one times the density of water, potassium only nine-tenths of the density of water. Some of the metals are characterised by their malleability and ductility; gold is the most malleable, silver, copper and tin are next in this respect; the most malleable are not the most ductile, as iron is more ductile than gold; but metals not malleable are not ductile, nor are those not ductile malleable.

Temperature has a powerful influence in determining the ductility and malleability of metals; thus, zinc is malleable and ductile at 300°, and at 600° is brittle and may be reduced to powder. The metals differ very much in tenacity, iron being the strongest, as a wire of it will sustain a greater weight than a wire of the same size of any other metal; copper ranks next, though only of half the strength of iron; platina, silver and gold are next in order, and the least tenacious of the metals are tin and lead. The fusing points of metals include an extensive range of temperatures: thus, mercury becomes fluid at 39° below zero, and platina can be fused only in the intense heat of the oxyhydrogen flame. Most of the metals are permanent; some, as mercury, zinc, cadmium, arsenic, tellurium, potassium and sodium, may be converted into vapour. Metals, with few exceptions, when exposed to the air, attract oxygen from it, and are converted into oxides; some are oxidised on the surface merely, others are entirely changed: gold, silver, platinum, palladium and mercury are not affected in this way; a rise of temperature increases the tendency to oxidation of those metals that attract oxygen at ordinary temperatures. The metals manifest a strong tendency to combine with chlorine; gold and platina unite with chlorine, though they are not oxidized by nitric acid; and several burn spontaneously when thrown, in a state of powder, into chlorine. At a high temperature most metallic oxides are decomposed by chlorine, a chloride of the metal being formed with evolution of oxygen. The metals combine with iodine, bromine, and fluorine; and the metallic compounds of sulphur are extensive and important; selenium and phosphorus unite with metals, holding nearly the same relations to them as sulphur. Tellurium, arsenic and antimony combine with hydrogen, forming gaseous compounds; and in these combinations the metals have the same relation to hydrogen as sulphur has.

The metals are found in nature in a variety of forms; some exist native, or as alloys with other metals; many are found in combination with arsenic; metallic chlorides and iodides exist native, but the compounds of metals with oxygen and sulphur are the principal sources whence they are derived. The name of *ore* is given to the native compound of a metal. Metals are separated from their ores by acting upon them with some substance which has a stronger affinity for the body combined with the metal than the metal has for it; thus, when a metal exists in combination with oxygen, it is only necessary to expose it to a powerful heat in contact with a fuel that will furnish carbon; carbonic acid will be formed, and the oxide reduced to the metallic state. A metal may be separated from sulphur by another metal that has a stronger affinity for sulphur than the one in combination. There are, however, various modes of reducing metals, the description of which does not come within the scope of this work.

POTASSIUM.

This metal, which is the base of potash, was discovered by Sir H. Davy; it was obtained by the action of a powerful galvanic battery upon a stick of caustic potash, slightly moistened so as to render it a conductor of electricity: water and potash were decomposed at the same time, oxygen appearing at the positive pole, hydrogen and potassium at the negative wire. The metal is now prepared in moderately large quantities by the decomposition of cream of tartar: this substance is first converted into carbonate of potash and carbon, by being ignited in a covered crucible; it is then mixed with coarsely powdered wood-charcoal, and exposed to a white heat in an iron bottle, from which the metal distils over into a cooled receiver, where it is protected from the action of air by naphtha, in which it must be preserved; the oxygen of the potash and of the carbonic acid unites with a fresh portion of carbon, and forms carbonic acid, which, by an arrangement of the apparatus, is allowed to escape. The metal prepared in this way is contaminated by carbon, and a compound which it forms with carbonic oxide; from these it is purified by distillation in cast-iron retorts. Potassium is soft at ordinary temperatures; at 32° it is brittle and crystaline, at 70° pasty, and at 150° fluid; its sp. gr. is 0·865, water being 1000; its colour is a bluish white, but if exposed for a moment to air it becomes grey, being converted into oxide (potash) on the surface; when heated it burns with a violet flame; it has such a powerful affinity for oxygen that water is decomposed in contact with it, so much heat being evolved that the hydrogen which is evolved will take fire and burn in connexion with the metal if air be present; the metal in this case is converted into a globule of dry potash, which combines with the water, the union being accompanied with a loud report.

Potassium combines with oxygen in two proportions, forming a protoxide ($KO.$) and a peroxide (KO_3.); the protoxide constitutes potash; once combined with water potash cannot be deprived of it except by combination with an acid; potash, therefore, as it is usually found is a hydrate, for perfectly anhydrous potash, in uniting with water, ignites. Hydrate of potash is familiarly known by the name of *caustic potash*. A solution of this caustic potash is prepared by adding to a boiling solution of carbonate of potash slacked lime in powder; the lime attracts the CO_2. forming carbonate of lime; the liquor of potash is known to be quite freed from CO_2. when no effervescence ensues upon the addition of muriatic acid. The solution, when evaporated to a certain extent, is poured into moulds, in which it solidifies; in this shape it has long been in use amongst surgeons, and was formerly called *lapis infernalis* or *devil's stone*, from its escharotic properties; when pure the hydrate is white, and of a crystaline fracture; it has a soapy feel from its dissolving the cuticle, with which it forms a soap; it has a strong action on all animal organic tissues; its solution is eminently alkaline, and to preserve it from access of CO_2., which converts it into a carbonate, air must be excluded. The different combinations of potash are of great interest, and are extensively used. The alkali with which it is most liable to be confounded is soda, from which it is distinguished by forming with an excess of perchloric, tartaric, and hydrofluosilicic, acids, sparingly soluble salts; soda, on the contrary, forming with these acids very soluble salts; chloride of platinum forms with solution of muriate of potash a fine yellow precipitate, but with a solution of soda no precipitate falls. Potash is composed of an equivalent of each of its elements, one of potassium 39·3, and one of oxygen 8·0; its combining equivalent is therefore 47·3.

Peroxide of *potassium* is a yellow powder, formed by burning potassium in an excess of oxygen gas.

Potassium combines with sulphur forming four different sulphurets. The *protosulphuret* may be formed by igniting in a crucible a mixture of charcoal and sulphate of potash; carbonic oxide is evolved, sulphuret of potassium remaining in combination, thus: $KO. SO_3 + 4C. = 4CO. + KS.$ If carbon, in a state of very minute division, be used in this process, the product will take fire on coming into contact with air, from its rapid combination with oxygen. *Tersulphuret* of potassium is formed by fusing together one part of sulphur and two of carbonate of potash; in this process carbonic acid is driven off, and the mass which remains consists of a mixture of tersulphuret of potassium and sulphate of potash; this is called liver of sulphur; it is of a liver brown colour, deliquesces in the air, and absorbs oxygen. If a solution of this substance be acted upon by an acid, water is decomposed, its oxygen going to the potassium to form potash, its hydrogen to a portion of sulphur to form sulphuret of hydrogen, and the remaining sulphur falls to the bottom as a white, and very minutely divided, mass, which is known by the name of *lac sulphuris*, or milk of sulphur. *Protosulphuret* is formed by decomposing sulphate of potash by sulphuret of hydrogen at a red heat. Potassium combines with selenium to form *seleniurets*; their constitution bears a close analogy to the sulphurets.

SODIUM (Na.).

THIS metal, in the state of chloride (common salt), exists in large masses, constituting salt mines; it is found dissolved abundantly in the waters of the sea and of salt lakes; it is also found in many minerals, and in the blood and fluids generally of animals. The discovery of sodium was made by Davy, in the same way as that of potassium; and it is now prepared in the same manner as that metal; but its preparation is attended with less difficulty. Sodium when thrown upon water is rapidly oxidized; hydrogen is evolved, but does not take fire, as in the case of potassium, unless the metal be kept from moving about on the surface of the water, when sufficient heat will be generated to set fire to the gas. The sp. gr. of sodium is 0·972; it unites with oxygen in two proportions, forming a protoxide (soda) and a peroxide; the latter is formed in the same way as peroxide of potassium, and bears a close analogy to it in all its properties. Pure dry soda is of a greyish white colour, and rapidly absorbs water, from which it can be freed only by combination with an acid.

Soda, though its alkaline action is decided, is not so strong an alkali as potash, and all its salts are decomposed by potash. The presence of soda may be discovered by the absence of any evidence of the presence of potash or ammonia, when the tests for these substances have been used; and the existence of a small quantity of soda may be discovered by its tinging the flame of the blow-pipe of a fine yellow colour. The compounds of soda are numerous and important.

LITHIUM (L.).

THIS metal has been isolated by the same means as the two last mentioned; it is white, and becomes oxidized on exposure to air; it is found in combination with a few minerals, from which it is obtained by a circuitous process. Lithia, which is a protoxide of lithium, is distinguished from the other alkalies by the sparing solubility of its carbonate; it tinges the flame of the blow-pipe of a bright red colour.

BARIUM (Ba. Βαρυς, *heavy*),

OBTAINED generally from the sulphate and carbonate of barytes which exist native. It may be prepared either by voltaic agency, or by passing the vapour of potassium over barytes heated to redness; the potassium combines with the oxygen of the barytes, and barium is set free; the residue is then heated with mercury, with which the barium amalgamates: the mercury is separated from this amalgam by distillation. Barium is a white metal; it rapidly decomposes water, forming barytes, with evolution of hydrogen. The native sulphate of barytes was long known by the name of *terra ponderosa*, or heavy spar. Pure barytes is procured by submitting nitrate of barytes to a red heat; it is a heavy grey powder, rapidly absorbs water when exposed to the air, and falls into a fine white powder—hydrate of barytes. Solution of barytes is caustic and alkaline, and rapidly absorbs carbonic acid from the air, forming insoluble carbonate of barytes; barytes is known by its soluble compounds, giving white precipitates with carbonate of soda and sulphuric acid, neither of which is affected by solution of sulphuretted hydrogen; the latter is also insoluble in nitric and muriatic acids: barytes is a protoxide of barium, consisting of one equivalent of each element. The soluble compounds of barytes are poisonous, and the carbonate being acted upon by the free acids of the stomach, is also rendered poisonous; the antidote is sulphate of soda or of magnesia, by which an inert sulphate of barytes is formed.

Sulphuret of barium (Ba. S.) is obtained by exposing sulphate of barytes in powder, mixed with lamp-black, to a powerful heat for two hours; carbonic oxide is evolved, and sulphuret of barium remains behind.

STRONTIUM (Sr.).

THE earth strontia is a protoxide of this metal, and is found native in combination with sulphuric and carbonic acids at Strontian in Scotland. The metal is prepared in the same way as barium, and is nearly similar to it in properties; it is distinguished from barium by imparting a rich crimson colour to the blowpipe flame. Nitrate of strontia is used to produce the red lights in fire-works; strontia may be separated from barytes by precipitating the latter by sulphurous acid.

CALCIUM (Ca.).

WE are indebted to Sir H. Davy for the discovery of this metal also; it is obtained in the same manner as barium; it is a white metal, heavier than water, which it rapidly decomposes, forming protoxide of calcium (lime), and setting hydrogen free. The protoxide, which is the only combination of calcium and oxygen, is found in great abundance; combined with SO_3. it forms sulphate of lime (plaster of Paris), and with C_2. it forms carbonate of lime (common limestone, marble, &c.); lime is also found in combination with phosphoric and arsenic acids, and with fluorine. Pure lime may be prepared by expelling the carbonic acid by exposure to a strong heat from pieces of marble; common limestone is deprived of its CO_2. on the same principle in kilns. Lime is a white earth; it absorbs water from the air, and falls to powder; it is then said to be slacked, and is a hydrate of lime. When lime is brought into contact with water, a hydrate is formed with evolution of heat sufficient to char wood and inflame gunpowder, when the process is conducted on a large scale. Lime is very sparingly soluble in water, and is more soluble in cold than in boiling water, one part of lime requiring 778 of water for its solution at 60°, and 1270 at 212°.

The solution of lime-water has a slightly acrid taste, and an alkaline reaction; when exposed to the air it absorbs carbonic acid and becomes covered with a pellicle of carbonate of lime; when the breath is passed through lime-water by means of a tube, the fluid becomes turbid, the CO_2. which is expired by the lungs forming carbonate of lime; this is redissolved by an excess of acid. Carbonate of lime is held in solution by excess of carbonic acid in most spring and river water. Solutions of lime give, with oxalic acid, a white precipitate not soluble in excess of the acid; nitrate of lime is soluble in alcohol and deliquescent; the flame of the blow-pipe is tinged of a brick red colour by the presence of lime. The use of lime in mortar is not owing to the formation of a carbonate, but to the drying of the hydrate of lime, by which the stones are retained in their places. Lime is employed in agriculture to decompose organic matter existing in the soil, and thus render it a proper pabulum for plants; its effects are best produced in soils such as peat, where large quantities of vegetable matter exist in a condition unsuited for absorption by the roots of plants. Calcium combines with sulphur in three proportions forming three *sulphurets.*

MAGNESIUM (Mg.),

DISCOVERED by Davy. It is best prepared by placing some pieces of potassium in the bottom of a tube of hard glass, and laying over these fragments of anhydrous chloride of magnesium; when heated nearly to the point of fusion the potassium is converted into vapour, which, coming into contact with the chloride, takes chlorine, leaving the magnesium free. It is a white silvery metal, malleable and fusible at a red heat; is slowly oxidized by damp air; does not decompose water; burns brilliantly, when heated to redness, in air or oxygen, forming magnesia; it inflames when thrown into chlorine; dissolves in dilute acids, forming a salt with the acid, and liberating hydrogen. Magnesia, which is a protoxide of the metal and the only compound of magnesium and oxygen, is found largely in water, its most abundant source being the magnesian limestone, which is a mixture of carbonate of magnesia and carbonate of lime. Carbonates, sulphates, and silicates of magnesia exist native. Pure magnesia is prepared by exposing carbonate of magnesia to a red heat, by which CO_2 is expelled; it is a very light, white powder, devoid of taste and smell; it is nearly infusible, and becomes, in common with lime, brilliantly phosphorescent when exposed to a powerful heat; it is very sparingly soluble in water, and more soluble in cold than in hot water. Magnesia is known by the entire solubility of its sulphate, which is decomposed by the alkalies and their carbonates; the precipitate is redissolved by adding strong solution of muriate of ammonia; the most delicate test for magnesia is to render the suspected liquor alkaline by ammonia, and then add a solution of phosphate of soda. A phosphate of magnesia and ammonia will crystalize on the side of the glass vessel; this salt is nearly insoluble in an alkaline liquor. Epsom salt is a combination of sulphuric acid and magnesia.

ALUMINUM (Al.),

OBTAINED by decomposing the chloride of aluminum with potassium, in the same manner as magnesium, the process being conducted in a platinum or porcelain tube, as the heat evolved during the operation would fuse glass; the metal is procured in small brilliant scales; it does not decompose water at ordinary temperatures; it dissolves rapidly in dilute acids and in alkaline solutions, liberating hydrogen by decomposition of water. Alumina is the only compound of aluminum and oxygen; it is found in nature more abundantly than lime; is a large constituent of almost all rocks, except pure limestone; it is the basis of clay and of most soils, and is usually combined with silica. The ruby and sapphire consist of alumina and small quantities of colouring matter; it is an indispensable ingredient in earthenware, and is used as a mordant to fix dyes in cotton or woollen cloths. Alumina, in combination with potash and sulphuric acid, constitutes alum, from which the name is derived. Pure alumina is obtained by decomposing a solution of alum by carbonate of potash; the SO_3. combines with the potash, CO_2. is evolved, and alumina precipitates; this is freed from sulphate of potash by solution in muriatic acid, from which it is again precipitated by carbonate of ammonia; when well washed and dried, this is a white hydrate of alumina; the water may be expelled by exposure to a white heat. Alumina suffers much contraction in drying; the amount of contraction calculated on a regular scale constituted the basis of Wedgewood's pyrometer. It strongly adheres to the tongue and moistened lips, owing to its attraction for water; and it is soluble in acids when dried at a moderate temperature. Alumina has a powerful tendency to unite with organic matter; if acetate of alumina be brought into contact with cotton cloth the salt will be decomposed, the earth being deposited on the cotton, and the acid freed; this property is extensively applied in calico-printing. It consists of two atoms of aluminum and three of oxygen, forming a sesquioxide; it is recognised by its solution giving a precipitate with the alkaline, carbonates soluble in the caustic, and fixed alkalies. A solid containing alumina, if moistened with a little solution of nitrate of cobalt, tinges the flame of the blow-pipe of a beautiful blue colour.

GLUCINUM, YTTRIUM, THORIUM, ZIRCONIUM, CERIUM, LANTHANUM.

These metals are obtained from very rare minerals, and in small quantities; they are not used in the arts, and are, therefore, comparatively unimportant. *Glucinum* is obtained from the beryl; glucina, its compound with oxygen, is a tasteless and inodorous earth; its salts have a remarkably sweet taste—hence its name (γλυκυς, *sweet*); the metal may be prepared from its chloride in the same way as magnesium and aluminum. *Yttria,* the oxide of yttrium, exists in some rare Swedish minerals, and has been found in the Bohemian garnet. *Thoria,* the oxide or earth of thorium, is found in two minerals of great rarity; it is the heaviest of the earths. *Zirconia,* the earth or oxide of Zirconium, is found in the hyacinth and zircon, two rare minerals; it resembles alumina in its properties, and, in some respects, silica, appearing to form a link between the metallic and non-metallic bodies. *Cerium* and *Lanthanum* are always associated together in nature, and have only recently been distinguished from each other; the latter received its name from having existed undiscovered in the oxide of cerium (λανθανω, *to lie hid*); it is not yet satisfactorily known.

MANGANESE (Mn.)

TRACES of this metal are found in the animal and vegetable kingdoms, and it is extensively diffused through nature, though not in large quantities. To obtain it, the oxide in fine powder is mixed with lamp-black and oil into a mass, and exposed in a covered crucible, lined with clay and charcoal-powder, for two hours to a strong heat; a button of the metal will be found in the mass. It is a greyish white, granular, brittle, very infusible metal, of sp. gr. 8·013; when exposed for some time to the air it forms a black powder, oxide of manganese; it decomposes water very slowly, and dissolves rapidly in dilute sulphuric acid, forming sulphate of the protoxide with evolution of hydrogen; it forms five compounds with oxygen—the protoxide ($Mn. O.$), sesquioxide ($Mn_2 O_3.$). peroxide ($Mn. O_2.$), manganic acid ($Mn. O_3.$), and permanganic acid ($Mn_2. O_7.$), and, in addition, the red oxide and varvicite, two complex oxides. The different compounds of manganese are obtained from the native peroxide, freed from oxide of iron by solution in muriatic acid and evaporating to dryness. In this process chloride of Mn. and perchloride of iron are formed, from which, when heated to redness, the perchloride is partly expelled in vapour and partly decomposed; by treating the mass with water a solution of protochloride of Mn. is obtained and insoluble oxide of iron. Protoxide of Mn. may be prepared by adding a caustic alkali to a solution of protochloride of Mn.; white hydrated protoxide of Mn. will be precipitated; this is rapidly converted into red oxide by exposure to air; the higher oxides are reduced to protoxide by exposure to a red heat in a stream of hydrogen. This oxide is greyish-green; it forms salts with acids, in some cases, as with SO_2. evolving much heat. *Sesquioxide* of Mn. is found native in the minerals *brannite* and *manganite*, and it may also be obtained artificially; it combines with acids, forming salts of a deep red colour; this oxide stains glass of a purple or violet colour. *Peroxide* of Mn., or *black oxide,* is the most frequent form of Mn.; it exists native under a variety of aspects. The mineral *pyrolusite* consists of Mn_2. in a pure and crystaline state, and in combination with one atom of water Mn. constitutes the mineral *wad.* Mn_2. may be prepared by decomposing the protochloride of Mn. by solution of chloride of lime—chloride of calcium and Mn_2 being formed; it is black, and when exposed to heat is converted first into sesquioxide, and then into red oxide; it does not unite with acids or alkalies; when heated with SO_3. or HC. it is decomposed, as in the preparation of oxygen on a large scale, and chlorine; it is used in the manufacture of glass. The $Mn. O_2$. of commerce is never pure, being mixed with carbonates of lime and barytes, and peroxide of iron: there are several ways of ascertaining the amount of pure peroxide in any specimen; the quantity varies from 60 to 70 per cent. $Mn. O_3$. is formed by igniting a mixture of caustic potash, or carbonate, or nitrate of potash with $Mn. O_2$. the fused mass which is formed dissolves in a small quantity of water, to which it gives a fine grass-green colour; this colour gradually changes; a brown powder is deposited, and the liquor is altered to a fine red. This substance got the name of *mineral chameleon.* The changes are owing to the formation of two distinct acids of Mn. The $Mn. O_2$. takes another atom of oxygen to form Mn_3. which combines with the potash. When a solution of this salt is diluted with boiling water, hydrated $Mn. O_2$. precipitates, and a crimson solution of permanganate of potash is formed. By treating permanganate of barytes with sulphuric acid a crimson solution of $Mn_2. O_7$. is obtained. It cannot be procured solid, for when heated to 100° it is resolved into $Mn. O_2$. and oxygen. Mn. in a solid form gives a purple glass with borax under the action of the blow-pipe, and a green one with carbonate of soda.

IRON (Fe.).

THIS is the most extensively distributed of the metals; it exists in nature in various forms. Metallic iron is found in loose blocks on the surface of the earth, and in veins of mines in Russia and America; its most abundant source is the oxide, either pure, as black and magnetic oxides, or red, or in combination with CO_2, as in the clay iron-stone, from which the iron of commerce is principally derived. Sulphurets of iron also exist in abundance, and arseniates, phosphates, sulphates, &c., have been found. Ærolìths, or meteoric stones, are found to consist of an alloy of iron, with nickel, chrome, and traces of other metals, covered with a glaze of earthy matter formed of certain minerals found in volcanic rocks. These bodies are supposed to have been expelled from volcanoes, which are known to exist in great numbers in the moon, and having passed beyond the limits of the moon's attraction, to have come within that of the earth's, and, therefore, gravitate towards its surface.

Iron is obtained from the clay-iron stone, by a process called smelting; the ore consists of oxide more or less pure, with alumina and silica. As carbon does not deoxidize silica, except under very peculiar circumstances, the metal cannot be prepared by merely deoxidizing the oxide of the ore; the decomposition of the silicate of iron is therefore effected by lime. The fuel (coal or coke) and the ore, mixed with limestone, are placed in the smelting furnace; the CO_2. of the limestone is expelled by heat; the lime when formed combines with the silicic acid, forming silicate of lime; the oxide of iron being thus set free by the decomposition of the silicate of iron, is reduced by the carbon of the fuel, which forms CO_2. The lime, silica, and alumina, fused together, form a substance of a nature between glass and porcelain, which floats on the surface of the melted metal, and constitutes the scoriæ, or slags, of the iron furnace. The metal obtained in this way is not pure, as cast-iron consists of the metal in combination with carbon, and is fusible, whereas the pure metal is almost infusible; this carburet of iron is mixed with variable quantities of silicon and phosphorus, constituting, according to their proportions, those varieties of the metal found in commerce. Cast-iron has a powerful tendency to crystalize in becoming solid, and then expands with great force; in this way it fills the smallest crevice of any mould into which it may be poured when in a fluid state.

Pure or malleable iron is made from cast-iron, by fusing it in a furnace exposed to a current of air; by this process the carbon is expelled, the iron becomes less fusible, and finally forms a granular mass; the heat being increased these grains agglutinate, and when worked up into a ball, are taken out of the furnace and subjected to great pressure, by which the soft particles of pure iron are welded together, and the fluid cast-iron expelled, if any remain. The malleable iron is then passed through a succession of rollers, by which it is converted into a bar, such as is found in commerce. This bar of iron differs very widely from cast-iron; it is soft, flexible, ductile, and malleable, none of which characters apply to cast-iron; it only becomes semifluid at the highest temperature, and cannot therefore be run into moulds; at a white heat it is of a doughy consistence, and several pieces of it may be kneaded into one by pressure; this process is called *welding.* Masses of iron, such as anchors, receive additional strength when formed in this way, by the welding of many small bars.

The form of iron called *steel* is intermediate in constitution between cast and bar iron; it contains about 1·5 per cent of carbon, and may be formed directly from the ore or from cast-iron, by adjusting the air and fuel in the furnace, so as to leave carbon enough to form steel. Steel may be obtained also by a process called *cementation,* which consists in exposing bars of iron imbedded in powdered charcoal to a red heat for some hours; the carbon gradually penetrates the iron, and steel is formed;

steel is harder and more fusible than pure iron; this peculiar hardness is imparted to it when it has been suddenly cooled after heating it to redness; it is then hard, brittle, and elastic, and is thus fitted for the manufacture of cutting instruments, &c. Steel when cooled slowly is soft, and the process of *tempering* consists in heating steel to a certain degree, and then allowing it to cool slowly.

Iron and steel enjoy the peculiar property of becoming magnetic. This property was first discovered in an ore of iron found near the town of Magnesia in Asia Minor, hence the name *magnetism*. The native loadstone is an oxide of iron; it has the power to attract pieces of iron and steel, which, while in contact with it, are capable of attracting other pieces; when detached, iron loses its magnetic property, steel retains it, and in this way artificial magnets are obtained.

Pure iron of a bluish white colour, malleable, ductile, and very brilliant: it is the strongest metal; its sp. gr. 7·8; intensely heated it becomes pasty and may be welded, a property which is participated in only by platina and sodium. When exposed in a mass to dry air it does not oxidize, but if exposed in a state of minute division to a gentle heat, it burns, forming peroxide of iron; when strongly heated in oxygen gas, it burns with great brilliancy, forming globules of black oxide of iron; if an acid be present iron will decompose water, forming oxide of iron, which unites with the acid to form a salt of iron; hence the rapid corrosion of iron in damp air, rust being a carbonate of iron. Iron dissolves in dilute sulphuric acid, with evolution of hydrogen, and at a red heat it decomposes water by abstracting its oxygen.

Iron, after being submitted to certain processes, acquires the property of becoming *passive*, that is to say, it loses all tendency to unite with oxygen; does not rust nor dissolve in acids, &c. This property is not peculiar to iron. Iron combines with oxygen in two proportions, forming a protoxide and a sesquioxide, and these unite again to form complex oxides, the black or magnetic oxides. *Protoxide* of iron cannot be obtained in a dry state, from the rapidity with which it absorbs oxygen; it forms the basis of the protosalts of iron, from whose solutions it is precipitated as a white hydrate, which soon turns green, and finally red, from absorption of oxygen; it exists native in the carbonate of iron and in all chalybeate springs. Peroxide of iron exists largely in nature; it constitutes the Elba iron ore, and in a hydrated state the *hematite;* it forms the red or yellow colouring matter of clay and the ochres. The protocarbonate of iron first formed is gradually converted into peroxide, by attracting more oxygen and liberating CO_2.; the ochreous deposit on the margin of chalybeate springs is formed in the same way. The peroxide may be precipitated from a solution of any of its salts by a caustic or carbonated alkali; if carbonated, the CO_2. is given off, as the peroxide does not combine with it; it combines with acids to form salts, which are all acid, and are easily decomposed. The *magnetic oxide* of iron is a complex oxide; its formula is $Fe. O. + Fe_2. O_3.$; it may be formed artificially, and constitutes the scales produced by the repeated heating and hammering to which iron is subjected: it is also produced, in other cases, when iron is oxidised at a high temperature. Iron has a remarkable affinity for sulphur, and combines with it in several proportions. The *protosulphuret* may be formed by rubbing a stick of sulphur on a rod of iron heated to whiteness; the sulphuret falls in drops from the rod. It may also be prepared by exposing a mixture of iron filings and sulphur in a crucible to a bright red heat. This substance dissolves in dilute acids, evolving sulphuretted hydrogen, and forming a salt of protoxide of iron; it exists sparingly in nature, and is dangerous, as sufficient heat is evolved, by its rapid absorption of oxygen when in the moist state, to set on fire the beds of coal near which it is sometimes found; in this case a protosulphate of iron is formed. The *sesquisulphuret* ($Fe_2. S_3.$) corresponds to the peroxide; it may be formed artificially, but is instable in its constitution. The *bisulphuret* is found native in very large quantity, and is called *iron pyrites;* it is found in a variety of forms, the most remarkable being where it assumes the shape of organic remains. The animal whose shape is simulated may be supposed to have died in water holding sulphate of iron, the oxygen of which being attracted by hydrogen, evolved during the organic decomposition, will have led to the formation of a deposit of bisulphuret. Of the *magnetic sulphurets of iron* the most remarkable is that which corresponds to the magnetic oxide; its formula being $Fe_3. O_4.$ or $Fe. S. + Fe_2. S_3.$; it is found at Barege, and may be formed by exposing bi- or sesqui-sulphuret to a red heat in close vessels. Seleniuret and phosphuret of iron exist, the latter generally in small quantity in cast-iron. Iron may exist in solution, either as protoxide, black oxide, or peroxide; and, as its detection is easier in the last condition, it may be converted into peroxide by boiling the solution to be examined with a few drops of nitric acid. A solution containing peroxide forms with water of ammonia a reddish brown precipitate of hydrated peroxide; with yellow prussiate of potash prussian blue; with sulphocyanide of potassium a deep blood red colour, without precipitate; with tannin or tincture of galls a deep violet or black; with sulphuret of hydrogen the separation of a deposit of pure sulphur takes place; and with hydrosulphuret of ammonia a black precipitate of sesquisulphuret of iron is produced. The red prussiate of potash forms Prussian blue with the protoxide, but not with the peroxide.

NICKEL (Ni.).

THIS metal was discovered in a mineral supposed to contain copper, which was called *Kupfer Nickel,* or deceitful copper, by the German miners. This mineral was found to be a combination of arsenic with a metal which retained the name of nickel. The metal is obtained by a circuitous process from the arseniuret, in the form of a very light sponge, of a silvery white colour, and more fusible than cast-iron; it does not rust on exposure to damp air; its sp. gr. is about 8·5; it is nearly as magnetic as iron, and retains its magnetism; its lustre is permanent, and its alloys are white and brilliant; added to brass in the proportion of one to five, it is used as a substitute for silver, constituting the German silver, nickel silver, argentine, and British plate, and also a metallic alloy, long known in China, called "packfong." Nickel combines with oxygen, forming protoxide and peroxide; it also forms compounds with sulphur, selenium, and phosphorus. Solutions of the compounds of nickel give with ammonia a green precipitate, which dissolves in excess of ammonia, forming a blue solution; yellow prussiate of potash forms with nickel solutions a white precipitate; they are not precipitated by sulphuretted hydrogen, and give a black sulphuret with hydrosulphuret of ammonia.

COBALT (Co.).

The miners of the middle ages having been disappointed in their expectations of a large produce from the ores of Cobalt, these having resisted all known means of extracting metal from them, regarded the mineral as under the protection of the Kobolds, or genii of the mines. The metal subsequently obtained from these refractory ores was termed cobalt; it exists in combination with arsenic and sulphur, and is always associated with nickel, from which it is separated with great difficulty, owing to the close resemblance in properties which they bear to each other. The metal is obtained from the native arseniuret; an impure oxide of cobalt is produced, known in commerce by the name of *zaffre;* the oxalate of cobalt prepared from this, when ignited, yields carbonic acid and metallic cobalt in a spongy form; it is reddish gray, more fusible than cast-iron; sp. gr. 8·5; and is not magnetic. Cobalt forms with oxygen two compounds—a protoxide and sesquioxide; it is recognised in solution by giving a blue precipitate with water of ammonia, which is redissolved in an excess of ammonia, forming a fine rose-coloured liquor which, if nickel be present, is brownish red. Cobalt has the remarkable property of colouring glass blue; the smallest particle of the metal may be detected in this way by the blow-pipe. Glass coloured deep blue by cobalt and ground to fine powder is employed to give to linen and to writing-paper a delicate shade of blue; the blue stains on porcelain and delft are imparted by cobalt; a pigment of alumina coloured by cobalt, called cobalt blue, is used as a substitute for ultramarine. The blue colours of cobalt are destroyed if brought into contact with chlorine or oxygen, black sesquioxide being formed.

ZINC (Zn.).

THIS metal is found in considerable quantity in nature, either combined with sulphur, forming sulphuret of zinc (*zinc blende*), or with carbonic or silicic acid forming the two kinds of *calamine*. From the volatility of the metal its reduction is conducted in crucibles or earthern retorts. The metal is first converted into vapour and condenses upon cooling. Zinc so obtained contains traces of carbon, iron, cadmium, and often arsenic; from these it is purified by distillation. It is a brilliant bluish white metal, of a crystaline texture, and of variable tenacity at different temperatures; it melts at 773°, and is volatilized at a full red heat; its vapour burns with a splendid white flame, forming clouds of oxide of zinc, which, from their lightness, were called by the older chemists *lana philosophica* (philosophers' wool). When exposed to even a moist atmosphere zinc is not oxidized beyond the surface, which becomes covered with a grey suboxide (?) not altered in the air; and it is on this account converted to many uses in domestic economy. In a galvanic circuit of two metals zinc is almost always positive, and prevents the corrosion of the other metal.

Pure zinc is little acted upon by acids; the ready solution in acids of common zinc is attributable to the presence of other metals.

The protoxide of zinc is the only oxide of the metal accurately known; it is formed when zinc is burned in air or oxygen, or when it is oxidized by decomposition of water; it may be prepared by decomposing a solution of sulphate of zinc: by carbonate of soda carbonate of zinc is precipitated, from which, when heated to redness, the carbonic acid is expelled, and pure oxide of zinc remains. The Zn. O. is a powerful base, neutralizes the strongest acids, and forms well-defined and characteristic salts. In solutions of the salts of zinc the caustic alkalies produce bulky white precipitates (protoxide), soluble in an excess of the alkali; hydrosulphuret of ammonia forms a white precipitate of hydrated sulphuret of zinc. The native *sulphuret of zinc* is a protosulphuret, and is found in a crystaline state of a variety of colours; it may be formed by fusing zinc and sulphur together.

CADMIUM (Cd.).

THIS metal is found in small quantity associated with zinc; it is rare and of recent discovery; it is obtained from ores of zinc, and is of a white colour like tin, more fusible and volatile than zinc; its sp. gr. is 8·69; it dissolves very slowly in dilute SO_3., and rapidly in dilute NO_5.; it forms with oxygen a protoxide, whose salts resemble those of zinc, from which they are known by giving with sulphuretted hydrogen a fine yellow precipitate. A native sulphuret of cadmium is found near Greenock.

TIN (Sn. from the Latin name *Stannum*).

THIS metal was extensively known in very early times; for, before the working of iron, instruments of bronze (an alloy of tin and copper) were in use. The chief source of tin are the mines of Cornwall, which were known to the Phœnicians; it is also brought from Mexico and the East Indies. The usual ore of tin is the native peroxide, from which it is easily reduced by smelting with the fuel; it is prepared by a process called *liquation*, which consists in gently heating the masses or "pigs" of tin until they begin to fuse, when the purer tin melts out: this is called *grain tin*, the residual mass *block tin*. Pure tin is white like silver, brilliant, and in malleability ranks after gold, silver, and copper; it is soft, easily bent, and has little tenacity; its sp. gr. is 7·3; it melts at 442°, being one of the most fusible of the metals; it oxidizes very slowly in contact with air and water, hence it is used for coating the surface of more oxidable metals. Tin unites with oxygen in three proportions. *Protoxide of tin* is thrown down as a hydrate when water of ammonia is added to a solution of protochloride of tin; when this hydrated oxide is heated in a retort filled with carbonic acid, its water is given off, and pure protoxide remains as a heavy black powder. Salts of tin may be formed by treating the hydrated oxide with acids. Protoxide of tin is remarkable for its tendency to combine with more oxygen, and by adding a solution of a protosalt of tin to a solution of any less oxidable metal, the latter will be reduced to its metallic state; salts of mercury, tin, gold, and platina, may be reduced in this way. The *sesquioxide of tin* is a combination of two atoms of tin with three of oxygen. *Peroxide of tin*, or *stannic acid* ($Sn. O_2.$), is produced in all cases where tin is allowed to combine freely with oxygen; it constitutes the common ore, *tin-stone;* it is readily prepared by acting on the metal in foil or powder with nitric acid, by which is produced a white hydrated peroxide, converted into a pale yellow peroxide when the water is expelled by ignition. There are three sulphurets of tin corresponding to the oxides; the *protosulphuret* is precipitated as a brown powder, by adding sulphuret of hydrogen to a solution of protochloride of tin; the *sesquisulphuret* is unimportant; the *bisulphuret* ($Sn. S_2.$) may be prepared by decomposing a solution of perchloride of tin by sulphuretted hydrogen. The precipitate Sn. S_2. is of a golden yellow colour, and is a strong sulphur acid. It may be prepared in the dry way, in which it has a peculiar interest, from its forming *mosaic gold*, the discovery of which confirmed the alchemists in their belief of the possibility of transmuting metals. Tin is recognised by the hydrosulphuret of ammonia, a golden yellow precipitate with solutions of the peroxide, and a brown one with those of the protoxide.

CHROMIUM OR CHROME (Cr. from χρωμα *yellow*).

THIS metal exists as chromic acid combined with lead or copper in some rare minerals, and in abundance as chromic oxide in chrome-iron ore, from which chromate of potash is prepared. The metal is obtained by exposing a mixture of the oxide, lampblack and oil, to an intense heat, in a crucible lined with charcoal. It is of a greyish white colour, very infusible and brittle; sp. gr. 5·9; it is not acted upon by dilute sulphuric or muriatic acid, but dissolves in hydrofluoric with evolution of hydrogen; it combines with oxygen forming an oxide, Cr_2. O_3. and an acid; the oxide may be prepared in a variety of ways, and forms the basis of an extensive class of salts.

Chromic acid (Cr. O_3.), is obtained by treating a solution of bichromate of potash with hydrofluosilicic acid gas; it forms with bases several important classes of salts, which are isomorphous with sulphates and manganates; its salts are coloured generally yellow, orange, or red. Chromium is distinguished by the remarkable colours of its compounds in solution, and by its oxide giving a green precipitate with the alkalies; Cr. O_3. is known by its producing with salts of lead a yellow, and with salts of black oxide of mercury an orange precipitate; Cr. imparts to glass a beautiful green colour, and is extensively used in staining glass and porcelain; many of its salts are employed as pigments and dyes.

VANADIUM (V.).

THIS metal derives its name from a Scandinavian deity; it is found as vanadic acid in vanadiate of lead, a very rare mineral. The formula of this acid is VO_3.; it resembles the chromic and manganic acids; the metal has been isolated, but nothing positive is known of its properties.

TUNGSTEN (symbol W. from the German name Wolfram),

FOUND in combination with oxygen as tungstic acid in native tungstates of lime and iron, by boiling which in strong muriatic acid, the lime is taken away, and the WO_3. remains as a yellow powder. Tungsten is reduced to the metallic state by exposing its oxides to a current of hydrogen at a full red heat. The metal resembles iron in appearance; its sp. gr. is about 17·5. Tungsten has the singular property of forming a substance nearly similar in appearance to gold; it is prepared by adding to fused tungstate of soda as much tungstic acid as it will dissolve, and exposing the product at a full red heat to a current of hydrogen; when the residual tungstate of soda is dissolved out, the new compound, which consists of one atom of soda and two of tungstic oxide ($Na.\ O. + 2\ WO_2.$), is obtained in scales and cubes of a splendid gold colour; these resist the action of acids and alkalies, and even of nitro-muriatic acid, in which gold is soluble, and it yields only to strong hydrofluoric acid.

MOLYBDENUM (Mo.),

FOUND in combination with sulphur and with oxygen in some minerals; it is a white metal; sp. gr. 8·6; acted on only by strong nitric and sulphuric acids, and by aqua regia.

OSMIUM (Os.)

EXISTS as an alloy of iridium, and is found in the ores of platinum, from which it is separated by a trouble-some process. It forms a highly volatile oxide of a most penetrating odour; from this property is derived its name (*οσμη odour*). The metal is reduced from the oxide in the shape of a black powder, which, by heat and compression, is rendered coherent and white. Os. combines with oxygen in three proportions.

COLUMBIUM or TANTALUM,

Found originally in an American mineral; from the difficulty of its extraction called *tantalum;* it is a black powder, which appears iron-grey when burnished. Hydrofluoric is the only acid that appears to have an action upon it; tantalum and silicon are nearly similar in chemical properties.

TITANIUM (Ti.)

Exists in a vast variety of minerals, though not in large quantities; when reduced from its native oxide (titanic acid) it is of a bright copper colour, and almost infusible. Titanium exists in most of the clay iron-stone, and, being reduced in the smelting of the iron, is found in the slags, in cubes of great hardness and brilliancy; sp. gr. 5·3; it is acted upon only by a mixture of nitric and hydrofluoric acid. Titanic acid ($Ti.\ O_2.$) constitutes the mineral *rutile,* and is also found in the mineral *anatase,* and more abundantly in *titanic iron* (ilmenite), the formula of which is $Fe.\ O.\ Ti.\ O_2.$

ARSENIC (As.).

This metal exists in nature in considerable quantity, and in a variety of forms. It is found native, but more generally in combination with nickel, cobalt, and iron; with sulphur it forms the native *orpiment* and *realgar;* and as arsenic acid it exists in the native arseniates of lime, iron, lead, &c. Arsenic is chiefly obtained in the roasting of cobalt ores; arsenious acid being formed, is carried, by the current of hot air that passes over the ignited ore, into a series of large chambers, where it is deposited on the walls and floors in the form of a fine greyish powder. This powder is resublimed to free it from oxides of other metals which discolour it, and is deposited in a vitreous mass. The best method of obtaining the metal from arsenious acid, is by heating it to redness, mixed with three times its weight of black flux*, in a crucible or earthenware retort. In using a crucible another cold crucible is inverted over it, in which the metal condenses; but it is deposited in the neck of a retort as a mass of rhombohedrons. It is a brittle metal; sp. gr. 5·96; sublimes at 356°, without previously melting; its vapour in contact with air has a garlic odour, which is not that of the metal, but of an oxide formed by a certain degree of combustion which occurs.

Exposed to the air, arsenic gradually falls into a grey powder of sub-oxide (*fly powder*); it is rapidly oxidized by nitric acid, and in melted nitre deflagrates violently; in fine powder it burns when thrown into chlorine, with a brilliant white flame; heated in oxygen it acts similarly: it combines with oxygen in three proportions, forming a sub-oxide (the composition of which has not been defined) and two oxides, *arsenious acid* ($As. O_3.$) and *arsenic acid* ($As. O_5.$).

Arsenious acid, or *white arsenic*, is found in commerce in milk-white opaque masses, which are colourless and transparent if recently sublimed, or the surface of the mass may be opaque, while the inner portions are transparent. In these different conditions, $As. O_3.$ has a different density and solubility; the transparent acid is of sp. gr. 3·74; 100 parts of boiling water dissolve 9·68 parts of it; the opaque acid is of sp. gr. 3·69; 100 parts of boiling water

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* Prepared by deflagrating together equal parts of nitre and cream of tartar. The nitrogen and oxygen of the nitrate of potash, unite with the carbon and hydrogen of the bitartrate of potash, forming carbonic acid, hydrogen, and water; the potash of both, and carbonate of potash, remain mixed with the excess of carbon which had escaped combustion.

dissolve 11·47 of it; a solution of the transparent has an acid reaction on litmus paper, that of the opaque a feeble alkaline reaction. The taste of $As. O_3$. is slightly sweet, leaving an acrid sensation on the palate; it sublimes at 380° without previously melting; slowly sublimed it condenses in exceedingly brilliant regular octohedrons; it is dissolved in large quantity by liquid muriatic acid, crystalizing from the solution in octohedrons. If the transparent acid be employed in this solution, the formation of each crystal is accompanied by a flash of light; those crystals are found to be opaque, and the evolution of light is probably owing to the alteration in the arrangement of particles, which takes place in the formation of opaque crystals from the transparent acid. Arsenious acid is that compound of the metal which, for its highly poisonous qualities, has been so often used to destroy life. The mode of detecting it is briefly as follows: in the first place, the vessels which have held the fluid in which the arsenic has been administered must be accurately examined, as the arsenious acid being a heavy and sparingly soluble powder, may have fallen to the bottom; any substance ejected from the stomach by vomiting, and, in case of death, the contents and mucous coat of the stomach must also be carefully examined. If this examination takes place some time after death, the particles of arsenious acid which adhere to the mucous coat are tinged yellow by the sulphuret of hydrogen evolved during decomposition of the body. If the powder of arsenious acid has been discovered, its properties will be found to be as follow:

When heated by itself in a glass tube the powder sublimes, and is condensed on the sides of the tube in brilliant minute octohedrons. When mixed with a little black flux, and ignited in a tube closed at one end, metallic arsenic sublimes, forming a steel-grey crust, brilliant on the side next the glass, dull and crystaline on the inner aspect; a garlic odour is perceptible at the open end of the tube: on cutting off the closed end of the tube, and heating the part containing the metallic deposit, the tube being inclined a little, the metal is vaporised, and arsenious acid is deposited a little higher up; the metal having combined with the oxygen of the air passing through the tube, the garlic odour is more decided in this case than in the preceding.

The white powder of $As.\,O_3$. dissolves in water, and gives precipitates with the following:

With *sulphuretted hydrogen*, a rich yellow precipitate (opiment), soluble in ammonia, and precipitated on the addition of an acid.

With *ammonia-nitrate of silver*, a canary yellow (*arsenite of silver*); this is a very delicate test, but excess of ammonia or of acids must be avoided as the precipitate is soluble in either.

With *ammonia-sulphate of copper*, a fine apple-green, soluble in excess of ammonia or of acid.

The fallacy to which these re-agents are liable may be corrected by attending to the following facts:

Sulphuretted hydrogen gives precipitates more or less like that of arsenic with cadmium, persalts of tin, antimony, and persalts of iron. The precipitate from cadmium is not soluble in water of ammonia. The precipitate from tin, when dried and ignited with black flux, gives no metallic sublimate. The precipitate from antimony evinces the same property as tin, and it dissolves in strong muriatic acid; the solution, when largely diluted, giving a white precipitate. Sulphuret of antimony is much more orange-coloured than that of arsenic. The precipitate from persalt of iron is pure sulphur, which, when heated, burns away, leaving no solid residue.

With *ammonia-nitrate of silver* phosphate of soda produces a yellow precipitate of tribasic phosphate of silver, exactly like the arsenite; it is much more soluble in ammonia, however, and they are at once distinguished by being collected and ignited; the arsenite gives off oxygen and arsenious acid, metallic silver remaining, whilst the phosphate gives no volatile product.

With the *ammonia-sulphate of copper* the arsenic precipitate is uncertain, unless the metal be reduced from it, as there are many basic compounds of copper which bear a close resemblance to it in colour. In all these cases reduction of the metal is the only positive test, and this becomes still more important when the fluid under examination is complicated with the contents of the stomach and intestines, in which case the arsenic must be converted into sulphuret, or into arseniuret of hydrogen. For the conversion into sulphuret the following is the process: The contents of the stomach and small intestines, or the matter vomited during life, are to be boiled in distilled water for half an hour, and the liquor then strained through a linen cloth. If the fluid be too thick to allow of the separation of a small quantity of precipitate, a current of chlorine gas is to be passed through it, by which most of the animal matter in solution is coagulated; the fluid, being strained again, is to be well boiled to expel the excess of chlorine, and then exposed to the action of a current of sulphuretted hydrogen gas.

The removal of animal matter may also be effected by acidifying the fluid with nitric acid, and then adding an excess of nitrate of silver; when the precipitate has been separated the excess of silver is to be thrown down by adding some solution of common salt, and the liquor, being filtered, is fit for the action of the sulphuretted hydrogen. When the liquor smells strongly of this gas there has been enough passed through, and it is to be boiled for a few minutes to expel the excess and assist the deposition of a precipitate, which is to be collected carefully on a filter, and, being washed with water, acidulated by muriatic acid, is to be dried at a moderate heat; when quite dry it is to be ignited, mixed with about twice its weight of black flux in a hard glass tube, closed at one end, when, if arsenic be present, it sublimes in the metallic form. Care must be taken not to soil the sides of the tube in introducing the materials.

The basis of Marsh's process is the formation of arseniuretted hydrogen, which is effected as follows :—The liquor having been freed from organic matter in the manner just stated, is rendered moderately acid by muriatic or sulphuric acid, and poured into a flask or bottle, to the neck of which is adapted a narrow tube of hard glass, which, after passing horizontally for a few inches, turns up and forms a narrow orifice; a piece of zinc being placed in the fluid, hydrogen is evolved, which combines with any arsenic present, forming arseniuretted hydrogen gas, which passes off through the glass tube.

When the jet of gas is ignited, if hydrogen alone be present, water is formed; but if a trace of arsenic exist the flame is whitish, and, on holding over it a piece of glass, a deposit is formed either of white arsenious acid, or of brown metallic arsenic, according to the height at which the glass is held over the flame. If the quantity of arsenic be too small to produce this effect it may be detected by igniting a portion of the horizontal arm of the tube; the arseniuretted hydrogen on passing this point will deposit its arsenic, which is carried by the current a little beyond the heated portion, and condenses in the metallic form; the smallest trace of arsenic may be detected in this way, as the arm of the tube may be kept red hot for some hours. If the liquor be still too thick from organic matter in solution, the gas bubbles will not break, but form a froth which passes into the tube, and mars the process. In this case the fluid may be so slightly acidulated as to cause a very slow evolution of hydrogen, and the tube, instead of terminating in a jet, is to be bent down so as to pass under the edge of a jar in the pneumatic trough, by which means the gas may be collected and examined; or the tube may dip under the surface of a dilute solution of nitrate of silver, or of sulphate of copper, by which the arseniuretted hydrogen is absorbed and decomposed, metallic arseniurets being formed, which may be reduced to the metallic state by the application of heat.

In conducting this process certain precautions must be taken. If the effervescence be rapid, it often happens that very minute portions of zinc or of the salt of zinc formed, are carried up, and being deposited on the plate simulate the appearance of arsenic. This is avoided by moderating the effervescence, or by passing the gas through a tube filled loosely with cotton, which arrests any mechanically diffused particles. Another source of error is the existence of arsenic in most of the zinc of commerce, and in sulphuric acid also. The purity of these substances should, therefore, be tested, by burning a jet of the hydrogen evolved by the action of the zinc and dilute acid simply, or passing it through a solution of ammonia-nitrate of silver for a quarter of an hour, when, if no trace of arsenic be detected, the suspected liquor may be added. Another source of error may arise from the compounds of antimony giving, under similar circumstances, a similar gas,—*antimoniuret of hydrogen.* This is distinguished from the arseniuretted gas by precipitating the salts of mercury, and of most metals, but not of copper, by depositing the metal at the heated part when a point of the tube through which it passes is heated to redness, whereas arsenic is deposited beyond the heated part; by the metallic crust not being volatilized at any temperature which can be applied to glass; and by the oxidation of the metallic scale of antimony on the plate of glass, with the outer flame of the blow-pipe forming a yellow powder whilst hot, and white when cold, which is not volatilized by any further application of flame, whereas arsenic becomes oxidized during vaporization only.

Arsenious acid possesses the property of preventing the putrefaction of animal substances, and, accordingly, the bodies of those poisoned by it do not quickly decompose. The $As.\ O_3$ forms, with fatty and albuminous matter, compounds not alterable under ordinary circumstances; hence the preservation of the stomach and intestines, though the rest of the body may have undergone complete decomposition. Instances of the entire body being preserved are furnished when the individual has lived sufficiently long after the administration of the poison to allow of the permeation of the arsenic through the tissues of the body generally, and, accordingly, when death has been the result of slow poisoning by repeated doses of the arsenious acid, the detection of arsenic through the entire body is rendered possible. A source of fallacy, however, may arise here from a resemblance of function which exists between arsenic and phosphorus. The latter element is almost constantly present in animal tissues, and the fact of the possibility of its replacement by arsenic has been recently established, so that a decision upon this point is manifestly difficult. The quantity of arsenic found naturally existing in animal tissues is very small, but the bare fact of its natural existence renders the certainty of its having been administered by no means conclusive when found in the body, as there is no absolute limit to the amount of it that may exist naturally. The most recently-discovered antidote to arsenious acid is the *hydrated peroxide of iron*. When this substance is made into a thin paste with solution of arsenious acid, arsenic acid and protoxide of iron are produced, which, uniting, form an arseniate of iron not hurtful to the system. In cases of poisoning, therefore, this hydrated peroxide should be quickly and profusely administered. It may be readily prepared by adding carbonate of soda to any salt of red oxide of iron, as permuriate, muriate or acetate tincture. When so prepared it need not be washed, as the muriate or acetate of soda will not mar its efficiency.

The sulphuret of arsenic (*King's yellow* of commerce), if taken as a poison, may be detected by its solubility in ammonia, from which it is again precipitated by an excess of any acid. It is easily reduced.

Arsenic acid ($As. O_5.$) is obtained by boiling eight parts of arsenious acid mixed with two parts of strong muriatic acid in a retort, gradually adding twenty-four parts of dilute nitric acid. When the mixture has been distilled to the consistence of a syrup it is to be transferred to a platina dish, and, when evaporated to dryness, white anhydrous arsenic acid is the residue. $As. O_5.$ dissolves slowly in water; deliquesces in vessels not kept carefully closed; it reddens litmus paper strongly, and forms perfectly neutral salts with the alkalies; at a high temperature it expels all the volatile acids, even the sulphuric, from their combinations. The compounds of $As. O_5.$ bear a close resemblance to those of phosphoric. $As. O_5.$ is precipitated golden yellow by sulphuretted hydrogen; the precipitate dissolves in ammonia and in excess of sulphuretted hydrogen, so that, if the quantity of arsenic be small, the liquor should be well boiled to show the precipitate. A solution of any arseniate gives, with nitrate of silver, brick red arseniate of silver; an insoluble arseniate, heated with charcoal powder, in a glass tube, will give a sublimate of metallic arsenic.

Arseniuret of hydrogen.—This substance is obtained in a gaseous state whenever nascent hydrogen comes into contact with metallic arsenic; as when an alloy of equal parts of zinc and arsenic is dissolved in dilute sulphuric acid, the hydrogen evolved combines with the arsenic. It is more easily prepared by immersing a piece of zinc in a solution of arsenious acid to which a little muriatic acid has been added; the hydrogen first evolved combines with the oxygen of the arsenious acid, reducing it to the metallic state, when it is taken up by the next portion of hydrogen produced.

Arseniuretted hydrogen is very poisonous; it burns with a brilliant white flame, water being formed, and arsenious acid, or arsenic, is deposited according to the amount of oxygen consumed by the flame; it is not absorbed by water; it decomposes most metallic solutions, precipitating metallic arseniurets; it is absorbed by dry sulphate of copper, water being evolved, and a blackish compound of sulphuric acid and arseniuret of copper being formed; if a small portion of chloride of mercury be heated in As. H_3. muriatic acid and arseniuret of mercury are formed. The important property of being decomposed at a red heat has already been mentioned.

Sulphur and arsenic combine in several proportions. Native *realgar* is a *bisulphuret of arsenic* (As. S_2.); it is a ruby red crystaline mass. *Yellow arsenic,* or *orpiment,* is a *tersulphuret of arsenic* (As. S_3.); it is a strong sulphur acid, forming with bases *sulpho-arsenites.* Sulphuret of arsenic may be reduced by igniting it with black flux, when the metal sublimes.

Persulphuret of arsenic (As. S_5.) is a strong sulphur acid, and forms with bases *sulpho-arseniates;* it may be reduced by heating with black flux. The substance called *King's yellow,* sold for killing flies, is properly made by boiling together lime, sulphur, and white arsenic; it generally consists of white arsenic coloured with sulphur; it is a sulphuret of the metal.

In the arts this metal is extensively employed. It is used to alloy the lead with which shot is made; in the manufacture of glass, to prevent the deoxidation of the oxide of lead; and in certain processes of dyeing, orpiment is employed to render indigo soluble.

ANTIMONY (Sb., from the Latin name *Stibium*),

FIRST employed as a medical agent by a monk named Basil Valentine, whose unpleasant experiments with certain compounds of the metal upon his brother monks obtained for it the name by which it is universally known. It is generally found as a native sulphuret, sometimes as an oxide, and occasionally as a mixture of both, forming the red antimonial ore (*oxysulphuret*).

It may be obtained pure by fusing the sulphuret at a bright red heat with black flux; sulphuret of potassium and oxide of antimony are formed, and the latter being decomposed by the carbon, carbonic oxide is evolved and metallic antimony remains. Antimony is a brilliant white metal of a highly crystaline fracture; it may be obtained crystalized in rhombohedrons by fusion; its sp. gr. is 6·8; it melts at about 800°, and is volatilized at a white heat; heated violently in air, it burns, forming a white powder of antimonious acid (*flowers of antimony*). Sb. takes fire in chlorine, burning with a yellowish flame; it combines with oxygen in three proportions.

Oxide of antimony is formed by adding carbonate of soda in excess to an acidulated boiling solution of chloride of antimony in water; muriate of soda is formed; and, as carbonic acid does not combine with oxide of antimony, this last is precipitated as a white powder, which becomes yellowish when heated. This oxide forms, with acids, salts of little stability; but with the acid potash salts of the vegetable acids, double salts of a remarkable character; the most important of these is the potash, or potassio-tartrate of antimony (*tartar emetic*). Oxysulphuret of antimony ($Sb.\ O_3 + 2\ Sb.\ T_3.$) may be prepared by roasting the native sulphuret in contact with air; the sulphur is burned out as sulphurous acid, and the antimony is oxidized. *Antimonious acid* ($Sb.\ O_4.$) is formed by igniting antimony after it has been freely oxidized either by combustion or by nitric acid; it is not soluble in water; not volatile, and combines with bases forming salts, from which it is thrown down as a hydrate by a stronger acid. *Antimonic acid* ($Sb.\ O_5.$) is formed when antimony is oxidized by an excess of nitric acid: it is a pale yellow red heat. Antimony combines with sulphur in three proportions; these compounds resemble its oxygen combinations; they are sulphur acids, and unite with bases to form a powder changed into antimonious acid by exposure to sulphur salts.

Sulphuret of antimony ($Sb.\ S_3.$) constitutes the common grey ore of antimony; native, it is of a dark grey colour, with a metallic lustre, of a crystaline structure, and is easily reduced to powder; it may be precipitated from a solution of any salt of oxide of antimony, as tartar emetic, by the addition of sulphuretted hydrogen, in the shape of an orange-red powder, which, upon fusion, assumes the colour of the native sulphuret. Sulphuret of antimony is soluble in alkaline solutions; when boiled in a strong solution of caustic potash it forms two salts, one containing sulphur, and the other oxygen, united to antimony and potash, the formula of which are $Sb. S_3. + 3KS.$ and $Sb. O_3. + 3KO.$; when the solution cools, a decomposition takes place, and a quantity of sulphuret and of oxide of antimony mixed, precipitate; according to Gay Lussac and Liebig, this is a chemical compound of the bodies named, and is an oxysulphuret; according to Berzelius, it is merely a mechanical mixture; it is of a fine orange-brown colour, varying in hue with the temperature; it is popularly called *kermes mineral,* from a supposed resemblance in colour to that given by the kermes insect. When the kermes mineral has precipitated, a further precipitation of the sulphur and oxygen salts may be caused by adding an acid in excess; this is called the *golden sulphuret of antimony;* when the acid has been added before the separation of the kermes, *brown or orange sulphuret of antimony* of the pharmacopœias is formed. A method of preparing these substances, by fusing together the materials, has been introduced. *Sulpho-antimonious acid* ($Sb. S_4.$) is formed as a yellow powder when solution of antimonious acid is decomposed by sulphuretted hydrogen. *Sulpho-antimonic acid* ($Sb. S_5.$) is produced when a solution of antimonic acid in muriatic acid is treated with HS.; it is a fine golden orange colour, and is the true *golden sulphuret. Antimoniuretted hydrogen gas* ($Sb. H_3.$) is formed when hydrogen is evolved in contact with antimony in a state of minute division; it may be obtained by dissolving zinc in dilute sulphuric acid, to which tartar emetic has been added; it bears a resemblance, in some respects, to arseniuretted hydrogen, from which it may be distinguished by the methods already detailed. In cases where tartar emetic may have become mixed with the substances suspected to contain arsenic, the metals may be separated by converting both into the gaseous hydrogen compounds, and then heating to redness the tube through which they pass; the antimony is deposited close to the heated part, and the arsenic a little beyond it. The existence of antimony in any substance is detected by its formation of arseniuretted hydrogen; the oxide in solution gives the orange precipitate with HS.; the precipitates with HS. in other stages of oxidation are more yellow, and are not volatile, which tests distinguish them from orpiment; by producing the antimoniuret of hydrogen they are known from the bisulphuret of tin, and from the bisulphuret of cadmium, by their solubility in hydro-sulphuret of ammonia.

TELLURIUM (Te.),

ONE of the rarest of the metals, assimilating very closely in its properties to sulphur and selenium; as a conductor of heat and electricity it is inferior to the other metals. Te. exists native, combined with a variety of metals, and its extraction from the ore is difficult; it is a very brilliant metal, and silvery white; and crystalizes in rhombohedrons; is brittle and easily powdered; sp. gr. 6·14; volatilizes at a high temperature, the vapour smelling like selenium; heated in air, it burns with a blueish flame, forming tellurous acid. Te. combines with oxygen, forming tellurous ($Te. O_2$.) and telluric ($Te. O_3$.) acids; it unites with hydrogen, forming *telluret of hydrogen*, which resembles sulphuret of hydrogen, particularly in its odour; it combines with the metals producing compounds precisely analogous to sulphurets.

URANIUM (U.)

EXISTS combined with oxygen in *pechblende* and some other rare minerals, from which it is obtained by a complex process. U. is of a dark grey colour, difficult to fuse; sp. gr. 9·0; it forms with oxygen a protoxide and a peroxide, the latter of which is used to colour glass of a lemon yellow.

COPPER (Cu.).

THIS important metal is extensively diffused through nature; it is found native in mines, often crystalized, and as arseniates, carbonates, &c.; its most abundant source is the native sulphuret. *Copper pyrites*, from which the metal is extracted, is a double sulphuret of copper and of iron. The reduction is conducted on the general principle for reducing sulphurets; but much care is necessary to separate it from iron, and to obtain it in a state fit for use in the arts. The metal is also obtained from the water which exists in copper mines; from this it is collected by throwing in fragments of iron, upon which it precipitates in crystaline masses. Pure copper is of a peculiar reddish colour, is very malleable and ductile, and in hardness ranks next to iron; by fusion it crystalizes in a form different to the native ore; its sp. gr. is 8·9; it is fusible at 1976°, and is not volatile; it is not tarnished in dry air, but in damp air becomes covered with a green coat of basic carbonate of copper; heated in contact with air it rapidly attracts oxygen, and forms black oxide after passing through a variety of colours. The acids generally do not act on copper at ordinary temperatures, unless in contact with air, as copper does not decompose water. At the point of contact with air oxygen is directly absorbed, and the acid forms a salt with the oxide so formed; in this way the acids contained in fatty substances act upon copper; nitric acid acts upon copper, giving off nitric oxide, and boiling sulphuric acid forms with it sulphate of copper, with evolution of sulphurous acid gas. Copper unites with oxygen in two proportions, forming a suboxide and a protoxide. This last is formed by exposing copper at a red heat to a current of air, or by igniting the nitrate of copper. It is a black powder which may be melted at a very high temperature, and crystalizes on cooling; it dissolves slowly in acids, forming the blue or green salts of copper; heated below redness in a current of hydrogen it is reduced, its oxygen combining with the hydrogen to form water; at a dull red heat it is reduced by carbon and all its compounds, carbonic acid being formed; for this reason it is used in the analysis of organic substances, the carbon of which it converts into CO_2., and the hydrogen into water. Copper thus obtained is a fine pink-red powder, having a powerful affinity for oxygen. Protoxide is precipitated as a hydrate in fine blue powder, when a solution of caustic potash is added to a solution of a salt of copper; this is decomposed by a very gentle heat. *Suboxide of copper* (Cu_2. O.) constitutes the ruby copper ore; it may be prepared by igniting a mixture of five parts of black oxide of copper and four of copper filings, half of the oxygen of the oxide unites with the metallic copper, and the whole is converted into suboxide; this is a reddish-brown powder, less affected by the action of moist air than pure copper, hence copper is coated with this substance to preserve it; the process for effecting this consists in covering the copper surface with red oxide of iron, which, when heated, is converted into protoxide; this is removed by digestion in a boiling solution of acetate of copper. There are two sulphurets of copper; both are found native, and may be prepared by fusing together sulphur and metallic copper. A thin slip of the metal burns in vapour of sulphur as iron does in oxygen. Sulphurets may be precipitated from the salts of copper by sulphuretted hydrogen. Copper is easily detected in solution; the salts of the black oxide are usually green or blue, and on the addition of ammonia a blue or green precipitate is formed, according to the acid with which the oxide has been united, and in all cases a deep violet colour is produced by an excess of ammonia; in this property nickel participates, but, independent of other means of recognition, the yellow prussiate of potash produces with copper solutions a chocolate brown precipitate of percyanide of copper. Sulphuret of hydrogen throws down a dark-brown precipitate, insoluble in hydrosulphuret of ammonia, and when a clean piece of zinc or iron is placed in a coppery solution, the copper is deposited on the zinc or iron in a metallic state. Salts of the suboxide give a white precipitate with ammonia, but as these salts are converted into protoxide very speedily, the tests already mentioned are sufficient. The deep ruby-red of stained glass is imparted by copper, and its salts tinge the flame of the blow-pipe blue or green; copper enters into the composition of a number of alloys. *Bronze* in 100 parts contains 90 parts of copper and 10 of tin; *gun metal* contains rather less tin; *bell metal* consists of 80 parts of copper and 20 of tin; Indian gongs are so constituted; common bells contain some zinc and lead, and less tin; *speculum metal,* used for constructing mirrors in reflecting telescopes, is composed of two parts of copper and one of tin; it is extremely hard and brittle, and when properly polished of great brilliancy. The different kinds of *brass* consist of alloys of zinc and copper in various proportions; the best *brass* is formed of four chemical equivalents of copper to one of zinc; the different varieties of counterfeit gold are formed by varying the proportions of the metals. *Hard solder,* used for connecting surfaces of brass and copper, consists of equal parts of zinc and copper.

LEAD (Pb. from the Latin name *Plumbum*).

THIS metal exists in a great many forms, and is extensively diffused; sulphate, phosphate, arseniate, carbonate, and chloride of lead are found; but the lead of commerce is obtained from the native sulphuret (*galena*). Lead is of a blueish white colour, very brilliant, but rapidly tarnishes on exposure to the air; it is soft; of little tenacity; it melts at 612°, and in solidifying diminishes in volume; by fusion it may be obtained in octohedrons; it is not volatile, not sensibly acted upon by muriatic nor sulphuric acid, but is rapidly oxidized and dissolved by nitric acid; its sp. gr. is 11·44. Lead is rapidly oxidized by exposure to air and moisture at the same time; the oxide so formed is partially soluble in water, and water contained in leaden cisterns may thus become impregnated with it; spring and river waters, however, contain small quantities of saline matter in solution, sulphates particularly, which, reacting upon the oxide of lead, form with it compounds insoluble in water; thus, the whitish crust which forms on the surfaces of leaden cisterns and pipes protects them from the oxidizing influence of the air. Lead forms a protoxide, a peroxide, and an intermediate complex oxide. The *protoxide* (Pb. O.) is prepared by exposing metallic lead at a red heat to a current of air; the oxide so formed fuses in cooling into a greenish-yellow coloured mass, the *litharge* of commerce, which is generally obtained in the process for extracting silver from ores of lead; litharge, when kept for some time, breaks up into coarse powder, assuming a brick red colour, which is produced by a change in its crystaline form. The yellow pigment named *massicot* is litharge in the yellow form. Oxide of lead seems to have the property of uniting with the alkalies and earths to form compounds more or less soluble; a compound of this nature, produced by boiling lime and litharge together, is used as a hair dye. The hair contains sulphur, which forms with the lead a black sulphuret. The hair so dyed, if detached from the head, will remain black for any length of time, and specimens are accordingly exposed in the windows of perfumers, &c.; but if the hair be dyed while growing on the head, it is tolerably certain to be converted into an interesting purple after a short time, particularly if the proprietor be a red-haired person. Pb. O. is soluble in 12,000 parts of water; it is the only oxide of lead which combines with acids. *Peroxide of lead* ($Pb. O_2.$) is produced by digesting protoxide in chlorine water, or in solution of chloride of lime: it does not form salts. *Red lead* or *minium* ($Pb_3. O_4.$) is produced when lead is oxidized without fusion of the oxide; the red lead of commerce generally contains an excess of protoxide, which may be removed by boiling in a solution of neutral acetate of lead. Red lead, when ignited, gives off oxygen, and becomes protoxide; it dissolves in nitric acid, forming a colourless solution, from which peroxide separates. The existence of other oxides is probable.

Protosulphuret of lead (Pb. S.), which constitutes the *galena* of commerce, is the only compound of lead and sulphur; it may be prepared by fusing together lead and sulphur, or by adding sulphuretted hydrogen, or hydrosulphuret of ammonia, to a solution of a salt of lead; the precipitate is a black powder insoluble in water, in alkalies and in dilute acids; by the action of nitric acid, it is converted into sulphate of lead. Lead is recognised by its solutions; giving with caustic potash a white precipitate, soluble in excess; with a carbonate of potash, a white one, not soluble in excess; with HS., the dark brown or black one already described; with solution of bichromate of potash, a fine yellow precipitate (*chrome yellow*); with iodide of potassium, a brilliant yellow iodide of lead. Yellow prussiate of potash gives a white precipitate; and sulphate of soda, a white sulphate of lead, insoluble in water. Independent of the uses of pure lead, which are too well known to need description, it forms important alloys. The metal of printers' types consists of three parts of lead to one of antimony; inferior qualities of pewter are alloys of lead and tin; the fine kinds contain some antimony and bismuth, with very little lead; common solder is composed of lead or tin; the more of the latter it contains the more fusible will the alloy be.

BISMUTH (Bi.)

THIS is a comparatively scarce metal; it is found in quantity only in the metallic state; it is obtained from the rocks in which it exists by igniting them when reduced to a coarse powder; the bismuth is fused out, and is collected at the bottom. Bismuth is white, with a peculiar shade of red, and has a marked crystaline structure; it may be procured in separate cubic crystals of considerable size; good crystals can be obtained only from the pure metal, which is prepared by deflagrating nitre on the surface of the melted metal; the impurities are first oxidized and mix with the scoriæ; these crystals often display beautiful rainbow tints, occasioned by a thin layer of oxide on their surface. Bismuth is very brittle, easily oxidized, scarcely acted upon by the muriatic and sulphuric acids; is rapidly oxidized by nitric acid with evolution of nitric oxide, and nitrate of bismuth is formed; it fuses at 497°; is volatile at white heat, and then burns with a blueish white flame; its sp. gr. is 9·9. *Oxide of bismuth* ($Bi. O_3$.) is prepared by the combustion of bismuth at a high temperature, or by the ignition of the subnitrate; it is a buff-coloured powder, and combines with acids to form salts. *Superoxide of bismuth* ($Bi. O_5$.), is prepared by boiling finely levigated oxide of bismuth in solution of chloride of soda. *Sulphuret of bismuth* exists native in crystals isomorphous with the sulphurets of antimony and arsenic. Solutions of bismuth give a brown precipitate with sulphuretted hydrogen and iodide of potassium, and a yellow one with chromate of potash; caustic and carbonated alkalies produce a white precipitate of hydrated oxide, insoluble in excess. A strong solution of a salt of bismuth is decomposed by adding water; a basic salt precipitates, and free acid exists in the liquor. Bismuth is employed extensively in the arts; the alloy used for stereotype plates consists of tin, lead, and bismuth; an alloy of two parts of bismuth, one of tin, and one of lead, fuses at 201°.

SILVER (Ag. from the Latin name *Argentum*).

THE principal sources of silver are the mines of South America and those of Saxony. A great deal of this metal is also obtained from the ores of lead in which the sulphuret of silver exists, generally in small amount. The native silver of South America is washed out by mercury, from which it is subsequently extracted by distillation, the mercury passing over and the silver remaining. In extracting silver from the sulphuret the ore is roasted, in a reverberatory furnace, with chloride of sodium; chloride of silver and sulphuret of sodium are formed; this last being washed out, the chloride of silver is put into barrels with some water, pieces of iron, and mercury; the iron decomposes the chloride of silver, forming chloride of iron, and setting the silver free, which forms with the mercury a fluid amalgam; a great part of the mercury is expelled from this by straining through leather bags, a pulpy mass of amalgam of silver remaining, from which the mercury is separated by distillation. Silver is extracted from the ores of lead by a process called cupellation; the lead is converted into oxide by exposure, in a dish made of bone ashes, at a full red heat, to a current of air. The process of cupellation has been much accelerated by the knowledge of the fact, that silver may be concentrated in lead by crystalization; the silver forms with a certain portion of the lead a fixed alloy, more fusible than the lead through which it is diffused, so that when a mass of the fused metal is allowed to cool slowly, the parts which first crystalize are pure lead; by repeating the process the great excess of lead is gradually removed and the quantity to be oxidized very much diminished.

The silver of commerce is freed from the impurities which it always contains by solution in nitric acid and precipitation by common salt; the chloride of silver then formed may be reduced in the usual way. Standard silver for coinage and plate is proved at the Mint by the method of assay with lead, already detailed. Pure silver is very brilliant; takes a fine polish; is the whitest of the metals; it is very ductile and malleable; its sp. gr. is 10·5; it fuses at 1173°; it is not altered by air, nor water, but when kept melted for a considerable time it absorbs oxygen, even to the extent of twenty times its volume, which it expels again on cooling, the surface of the metal being thrown into irregular granulations; the oxygen in this case appears to be held in solution by the metal. Silver is very soft, and that used in coin and plate is therefore alloyed with copper; the silver coin consists of 37 parts of pure silver to 3 of copper. When exposed to the air silver tarnishes after some time, a sulphuret being formed by the sulphuretted hydrogen existing in the atmosphere evolved during the decomposition of organic matter. Silver is not acted upon by sulphuric and muriatic acids, but is dissolved by nitric acid with evolution of nitric oxide gas. Silver forms three oxides, of which the protoxide only is well known.

Protoxide of silver (Ag. O.) may be prepared by adding caustic potash, or lime-water to a solution of nitrate of silver; a brown powder is thrown down, which, when dried by a gentle heat, becomes black; when strongly heated it is resolved into oxygen and metallic silver; this change occurs at ordinary temperatures if it be placed in contact with organic matter; with acids it forms salts, and with ammonia *fulminating silver*. Heated with glass silver is converted into oxide, which stains the glass of a deep yellow or orange colour. *Sulphuret of silver* is found native, both pure and in combination with other sulphurets; it is the most abundant ore of silver. Solutions of silver are precipitated by the sulphites, by protosulphate of iron, and by protochloride of tin. Silver being reduced, muriatic acid, or solution of common salt, throws down a white chloride of silver, insoluble in water and in acids, but soluble in water of ammonia; exposed to light, in contact with organic matter, chloride of silver is tinged violet or black, owing to the formation of a subchloride; hence its use in photographic processess. Solutions of silver give with iodide of potassium a canary yellow precipitate insoluble in ammonia, and with sulphuret of hydrogen a deep brown sulphuret.

MERCURY (Hg. from the Latin name *Hydrargyrum*, *ὑδωρ water, αργυρεος silvery*).

THIS metal is found native, and in combination with gold and silver; it is chiefly extracted from its native sulphuret (*cinnabar*). The process of reduction consists in distilling the ore with lime, or iron in small pieces; in one case, sulphuret of calcium is formed, and mercury and oxygen are liberated; in the other, sulphuret of iron is formed, mercury being left free; another process consists in roasting the ore in kilns, by which mercury is driven off in vapour along with sulphurous acid; this last being allowed to pass off the mercury is collected by condensation in a chamber lined with leather, upon which it is deposited. The quicksilver of commerce is contained in long iron bottles; it generally contains portions of tin, lead, and bismuth, introduced as adulterations; from these it may be freed by distillation, or by being left in contact with dilute nitric acid. Mercury having less affinity for oxygen than the other metals, is the last dissolved, so that when the dilute acid is found to contain mercury, the mass may be looked upon as pure. Mercury is known by its fluidity at ordinary temperatures; it is of a brilliant silvery hue; if pure is not tarnished in dry air, but in damp air its impurities are oxidized rapidly, a galvanic circle being formed by the mercury and other metals; it becomes solid at 39°, and crystalizes in octohedrons; its sp. gr., when solid, is 14·0, when liquid, 13·5; it boils at 662°, forming a colourless vapour; at its boiling point, and a little below it, mercury absorbs oxygen from the air, forming oxide, which is decomposed at a red heat. Sulphuric and muriatic acids do not act upon mercury at ordinary temperatures; nitric acid oxidizes it rapidly; boiling oil of vitriol is decomposed by mercury, sulphurous acid and oxide of mercury being formed. There are two oxides of mercury. The *suboxide* (Hg_2. O.) is best prepared by agitating chloride of mercury (*calomel*) in solution of potash or lime; chloride of potassium or of calcium is produced and suboxide; this is a black powder, which must be dried in the dark with a gentle heat; when heated it is resolved into metallic mercury and protoxide; this change occurs gradually on exposing it to light; suboxide forms salts with acids. *Protoxide of mercury* ($Hg. O.$) may be prepared by any one of the following methods: by exposing mercury, at a little below its boiling point, for a long time to the action of air; the metal is gradually converted into small deep red crystals of protoxide, the *red precipitate per se* of the earlier chemists; or by heating crystals of nitrate of mercury till the nitric acid and water have been driven off, when an orange red crystaline powder is obtained; or by decomposing a solution of bichloride of mercury by caustic potash or lime-water; a canary-yellow hydrate is thrown down, which becomes of a deeper colour when dried: red precipitate, when finely powdered, assumes the same yellow hue. The protoxide is slightly soluble in water, and the solution has a feeble alkaline reaction; with acids the protoxide forms salts; at a full red heat it is resolved into mercury and oxygen; its colour changes with the temperature, becoming nearly black when very hot. *Subsulphuret of mercury* ($Hg_2. S.$) is formed when any salt of the suboxide is decomposed by hydrosulphuret of ammonia; it is a black powder, resolved into mercury and protosulphuret by the application of heat. *Protosulphuret of mercury* ($Hg. S.$) constitutes the *cinnabar* of commerce; it may be prepared by fusing sulphur in a crucible, and adding six parts by weight of mercury; a combination takes place with evolution of considerable heat; the compound is first black, but changed to a deep red by subliming it in glass vessels. In this state it constitutes *factitious cinnabar*, from which vermilion is prepared, by exposing it in a finely levigated state, and covered with a thin layer of water, to a strong light. Protosulphuret may may be obtained by other processes. The presence of mercury in solution may be ascertained by immersing a clean slip of copper in the fluid; the mercury will be deposited upon the copper in the form of a grey powder, which consists of minute globules; protochloride of tin and phosphorous acid precipitate mercury in the metallic state, and the globules may be aggregated by boiling the fluid. Any solid containing mercury, when ignited in a tube of hard glass, yields a sublimate of metallic mercury; if in very small quantity, this appears as a ring of grey powder, which is found upon examination with the microscope to consist of minute and brilliant globules; the sublimation in this case is facilitated by the addition of a little carbonate of potash. Salts of the suboxide give with caustic alkalies black or grey precipitates; sulphuretted hydrogen throws down a black subsulphuret; solution of common salt produces calomel; and bichromate of potash forms an orange chromate of the suboxide. Salts of the red or protoxide are precipitated yellow by an excess of caustic potash, and white by ammonia; sulphuretted hydrogen forms a black protosulphuret; and iodide of potassium a red precipitate soluble in excess of iodide. The colour of these precipitates is varied by the acid with which the oxide may be combined; but in all cases ammonia gives a black precipitate with the salts of the suboxide, and a white one with salts of the red oxide. By triturating mercury with sulphur, or with other substances of little activity, a small portion only of the metal enters into combination, the remainder being mechanically mixed.

GOLD (Au. from the Latin *Aurum*).

GOLD is found only in the metallic state, pure or alloyed with other metals, generally with silver, tellurium, and mercury. The gold of commerce is for the most part obtained by washing the sand formed by the detritus of rocks of igneous origin in which the metal is generally distributed. If gold be found alloyed with silver the latter is dissolved out by nitric acid. Pure gold is yellow, very malleable and ductile, and nearly as soft as lead; gold coin is therefore alloyed with copper in the proportion of 83 parts of copper in 1000. Gold evinces no tendency to combine with oxygen or sulphur, and is, therefore, not altered by exposure to air; it fuses at 2016°; its sp. gr. is 19·5; it is not acted upon by any single acid, but dissolves in a mixture of nitric and muriatic acids, and in a mixture of nitric and hydrofluoric acids. Gold forms two oxides, obtained by the decomposition of its chlorides. Deutoxide of gold ($Au. O_2.$) is a green powder: it does not combine with acids, and in solution of caustic potash is resolved into metallic gold and peroxide. *Peroxide of gold*, or *auric acid*, ($Au. O_3.$) is formed by decomposing perchloride of gold by an excess of magnesia; aurate of magnesia is precipitated, which is decomposed by nitric acid; the perchloride remains as a reddish hydrate, which when dried in the air, turns brown, and at 212° gives off water and becomes black; it does not combine with any acid; with muriatic acid perchloride of gold is formed; it combines with alkalies, and the precipitates formed by solutions of gold with a caustic alkali is a compound of auric acid with the base; auric acid in powder or solution is rapidly decomposed upon exposure to the light, metallic gold being produced. The metal is deposited from its solutions by any of the deoxidizing agents; by protosulphate of iron it is thrown down as a brown powder, which, when burnished, assumes the appearance of the metal; protochloride of tin occasions a fine purple precipitate, called the *purple of Cassius*, which is probably a compound of oxide of tin and suboxide of gold; it is soluble in water of ammonia; and mercury digested on it does not dissolve out any metallic gold; when exposed to a red heat it is resolved into a mixture of peroxide of tin and metallic gold, the purple colour still remaining; it is used for painting glass and porcelain. Gold when heated on the surface of glass stains it of a rich purple colour, being probably oxidized. Sulphurets of gold are formed by decomposing the chlorides by sulphuretted hydrogen; they are brown powders. The value of alloys of gold is ascertained in a variety of ways; one of these is by comparing a streak left by it when drawn across the surface of certain stones with the streak made by a known alloy of the metal; the stones generally used are the touchstone, which is a variety of flinty slate, and basalt, of an uniform black colour.

PALLADIUM (Pd.),

FOUND in small quantities associated with platinum; its general characters are similar to those of platinum; it is white; almost infusible; admits of being welded; is malleable and ductile, and of sp. gr. 11·5: heated below redness its surface appears blue and green from the formation of oxide. The metal is not sensibly acted upon by muriatic or by sulphuric acid, but is dissolved by nitric acid; it forms three oxides. Solutions of palladium are recognised by giving a flesh red precipitate with ammonia, soluble in excess; with cyanide of mercury a white precipitate is formed, and with iodide of potassium a black one.

PLATINUM (Pt.).

THIS metal was originally found in the sands of some South American rivers, and, from its likeness to silver (plata), was called platina, or little silver; it has since been found in considerable quantity in the Oural mountains, which separate European from Asiatic Russia. Platina exists native, associated with a great variety of metals; it exists in rocks of igneous origin, and in the sands of rivers flowing over them. The process of extraction from the ores is very complicated. Pure platinum is white, but not so brilliant as silver; it is the densest of bodies, its sp. gr. being 21·5: it is very malleable and ductile; it is fusible only in the oxyhydrogen flame; at a high temperature it may be welded. Platinum may be reduced to a state of minute division in two ways. *Spongy platinum* is prepared by dissolving chloride of platinum and sal-ammoniac separately in alcohol, and mixing the solutions; a fine yellow powder, chloride of platinum and ammonium, is produced, which, while moist, is made into balls like peas, and heated to redness; chlorine is carried off by the hydrogen of the ammonia, and platinum remains as a light grey sponge. *Platinum black* may be prepared by precipitating a solution of bichloride of platinum with zinc, and boiling the precipitate in muriatic acid, or by dissolving protochloride of platinum in a boiling solution of potash, and adding alcohol gradually until effervescence ceases. The precipitate after being boiled in succession in alcohol, muriatic acid, potash, and water, is a dull black powder consisting of pure metallic platinum; it absorbs oxygen in a large quantity, and is employed in organic analysis. Platinum does not combine with the oxygen of the air, but is slightly oxidized when nitre or potash is fused in contact with it; it dissolves only in the nitro-muriatic and hydro-fluoric acids. There are two oxides and two sulphurets of platinum. When a slip of zinc is placed in a solution of platinum, the latter is separated as a black powder, soluble in aqua regia, and giving with an alcoholic solution of sal-ammoniac a fine yellow crystalline precipitate; with iodide of potassium a black precipitate, soluble in excess, producing a rich crimson solution. This metal is sometimes used in enamelling on glass and porcelain, but it is chiefly employed for the manufacture of large boilers for concentrating oil of vitriol; and small crucibles constructed of it are extensively used in chemical operations.

IRIDIUM (Ir.) and RHODIUM (R.).

THESE metals are found associated with platinum. Iridium is like platinum, but less fusible; it is white and very brilliant; sp. gr. 18·68; it is insoluble in acids, but, when reduced to the spongy form, is soluble in aqua regia; it combines with oxygen in four proportions.

Rhodium is white, very brittle and hard; sp. gr. about 11·0; it is not acted on by aqua regia, except when alloyed: its name is derived from the rose-colour of its solutions (*ῥοδεος rosy*); it unites with oxygen in two proportions.

THE SALTS.

The substances known in chemistry under the denomination of salts, may be divided into two classes. The first comprising such as are formed by the union of a simple body analogous to chlorine with a metal. Chloride of sodium is of this class; these are called *haloid salts* (ἁλς *the sea,* and ειδος *a likeness*), from their resemblance to common salt. The second class comprehending the salts formed by the combination of acids with bases. Salts are said to be either *neutral*, *acid*, or *basic*. A neutral salt does not exert either an acid or an alkaline reaction; it generally consists of one equivalent of acid with one of base, the latter containing one equivalent of oxygen; sub or protoxides are the bases therefore of true neutral salts. The salts of sesqui and deutoxides generally have an acid reaction, except when there is an excess of base. Metallic oxides combine in their neutral salts with one equivalent of acid for each equivalent of oxygen contained in the base; thus a suboxide or protoxide unites with one equivalent of acid, a sesquioxide unites with three equivalents of acid. The salts, though they may have an acid reaction, are termed neutral, owing to the equality of proportion of the acid with the oxygen of the base.

Basic salts are those in which there exists more than one equivalent of base for each equivalent of acid. Haloid salts combine frequently with the oxide of the metal which they contain, and form *basic haloid salts;* thus chloride of copper unites with oxide of copper, forming basic chloride of copper. These compounds are generally called *oxychlorides, oxyiodides*, &c., as the case may be. In addition to neutral salts, which are *mono-basic,* or contain one equivalent of base and one of acid, there are *bibasic* and *tribasic* salts, having two or three equivalents of base to one of acid respectively; these are considered neutral, whether their action be acid or alkaline, being derived from a definite combination of the acid with basic water. *Double salts* are obtained by the union of two simple salts; both salts generally contain the same acid, but different bases. Salts of different acids, with the same base, may combine to form double salts, as the oxalate and nitrate of lead; and there are a few examples of a double salt containing two acids and two bases. *Sulphur salts* consist of a sulphur acid, which is generally a sulphuret of an electro-negative metal or of carbon, combined with a sulphur base, which is a sulphuret of an electro-positive metal. The *hydracids*, as the acid compounds of hydrogen with simple bodies are called, do not unite with metallic oxides to forms salts, but they are decomposed, water being formed; and by the contact of these hydracids with metals hydrogen is expelled; the hydrogen in such cases, according to the metallic theory of its constitution, acting the part of a base, which is expelled by the greater affinity of another base for the second element of the hydracid.

The similarity in properties existing between a compound consisting of chlorine, or of an element of that class, with a metal, and a salt composed of an oxygen acid and the oxide of a metal, has led to the suggestion of a theory which assumes, that, at the moment of union of an oxygen acid with a metallic oxide, a new arrangement of elements takes place, by which the salt is assimilated in constitution to that of a compound of chlorine with a metal; as, for instance, that in sulphate of magnesia there is neither sulphuric acid (SO_3.) nor magnesia (MgO.), but sulphur, oxygen, and magnesium. This view, which has been called the binary theory of salts, is pretty generally adopted, but the nature of this work forbids the discussion of the arguments for and against it.

CHEMISTRY OF THE MOST IMPORTANT SALTS OF THE INORGANIC ACIDS AND BASES.

Chloride of potassium (K. Cl.) may be prepared by neutralizing potash with hydrochloric acid; it exists in abundance in salt springs and in the ashes of plants; it is very soluble in water, and is used as a freezing mixture, in consequence of the cold produced during its solution; it crystalizes in anhydrous cubes, and its chief use is in the manufacture of alum.

Iodide of potassium (KI.) may be prepared in a variety of ways. One of the simplest of these is by neutralizing solution of potash with iodine; iodide of potassium and iodate of potash are formed by the solution being evaporated to dryness: the residual mass is heated to redness, and kept fused while any bubbles of oxygen gas are given off; the remaining iodide, when cold, is to be dissolved in water, and allowed to crystalize very slowly. If the heat in this process be too high, a loss will occur, and, if it be not high enough, undecomposed iodate of potash will remain, with which, from its increasing the product, the salt is often adulterated. Mr. Scanlan has proposed a test for the detection of the iodate, which consists in adding tartaric acid to the suspected solution; if pure iodide only be present the acid has no action save the liberation of hydriodic acid; but if iodate be present iodic acid is liberated, which reacts upon the hydriodic acid by which water is formed, and the iodine liberated may be detected by the starch test. KI. crystalizes in cubes, and sometimes in square prisms; it is not deliquescent when pure, and has no action upon turmeric paper, by which its adulteration with carbonate of potash may be detected. This salt is sometimes mixed with chloride of potassium; the adulteration may be detected by decomposing the solution with nitrate of silver, and then washing the precipitate with water, digesting it in strong water of ammonia and filtering; if the solution, rendered slightly acid with nitric acid,

[illegible]

[illegible] manufacture of gunpowder. [illegible] furnishes to [illegible] gunpowder forms [illegible] times its volume.

Were this expansion to occur instantaneously it would burst any body without exerting a projective force; but the decomposition of gunpowder occupies some time; the formation of gas is therefore progressive to a certain extent, and the ball is propelled through the barrel of the gun with a force equal to the power of the whole amount of gas generated. The products of decomposed gunpowder are sulphuret of potassium, nitrogen, and carbonic-acid gas. The proportions of sulphur, saltpetre, and carbon (charcoal) employed for the manufacture of gunpowder in the government factories of three leading states are as follow:

	English.	French.	Prussian.
Sulphur	10·0	12·5	11·5
Carbon	15·0	12·5	13·5
Saltpetre	75·0	75·0	75·0
	100·0	100·0	100·0

Coarse blasting-powder consists of 65 parts of saltpetre, 20 of sulphur, and 15 of charcoal. Excess of sulphur increases the explosive force, but it is of too corrosive a quality to be used in fire-arms. A mixture of 3 parts of saltpetre, 4 of carbonate of potash, and 1 of sulphur is decomposed instantly, when fused, with an explosion so violent that, if it occur on a thin iron plate, the plate will be perforated. A mass composed of 3 parts of nitre with 1 of finely-powdered charcoal, if touched with an ignited coal, will burn nearly as fast as loose gunpowder, but without explosion. The intensity and rapidity of the deflagration of gunpowder is therefore regulated by the sulphur, and the gas, to which its projective force is due, is generated by the carbon. Great precaution is necessary in the preparation of the materials for the manufacture of gunpowder. Success depends in a great measure on the proper preparation of the charcoal. This should be the product of a light wood, forming little ashes, such as birch, and be carbonized in cylinders slowly, and at the lowest possible heat. Charcoal so prepared, when reduced to a very fine powder, is so inflammable that it sometimes takes fire at ordinary temperatures. The nitre is purified by repeated crystalizations, and by washing the crystals with water already saturated with nitre; this dissolves any common salt that may be present and does not act upon the crystals of nitre.

Hypochlorite of potash ($KO. Cl O.$) is formed by passing a stream of chlorine gas into a solution of carbonate of potash.

Chlorate of potash ($KO. Cl O_5.$).—By passing chlorine into a strong solution of potash, chloride of potassium and hypochlorite of potash are formed; by boiling the liquor oxygen is given off, chloride of potassium and chlorate of potash are formed; the salts are separated by crystalization. Considerable saving is effected in the preparation of this salt by the method proposed by Professor Graham, which is as follows:—one equivalent of carbonate of potash mixed with one of hydrate of lime (by weight about two of the first to one of the second) is exposed to a current of chlorine; the gas is absorbed, the solid mass becomes very hot, and water is abundantly given off; chloride of potassium, carbonate of lime, and chlorate of potash are formed, whilst water is given off; by treating the mass with water the potash salts are dissolved, and the chlorate may be separated by crystalization. Chlorate of potash crystalizes in rhomboidal tables, of a pearly lustre; it is anhydrous; 100 parts of water dissolve 3·5 parts at 32°, and 60 parts at 212°; it tastes somewhat like nitre; when heated it melts, evolving oxygen, being converted into chloride of potassium and hyperchlorate of potash; the heat being increased pure chloride remains; it forms the basis of many deflagrating mixtures, from its affording a ready supply of oxygen; when rubbed in a mortar with sulphur, or with sulphuret of antimony, it explodes violently; placed in contact with a small piece of phosphorus on an anvil and struck by a hammer it detonates dangerously. The greatest care should be observed in experimenting with this salt. The compositions employed in the manufacture of common lucifer matches consist of mixtures of chlorate of potash with charcoal and sulphur, or sulphuret of antimony, or cinnabar, made into a paste, with mucilage of gum arabic and applied to the stick previously smeared with sulphur.

Perchlorate of potash is remarkable only for its being one of the least soluble salts of potash; it may be used as a test for the detection of potash. *Silicate of potash* is important as being a constituent of glass. Iodate of potash may be obtained by neutralizing perchloride of iodine with caustic potash.

Chloride of sodium—common salt—sea salt (Na. Cl.).—This salt exists in nature in great abundance; it is found solid, as *rock salt,* and in solution in the waters of the sea and of salt lakes. Beds of salt are sometimes of great extent; that at Northwich is supposed to be 60 feet thick, a mile and a half long, and 1300 yards wide; and the salt mines of Poland are of still larger dimensions. The deposits of such large quantities of salt have probably taken place from the drying up of salt lakes. Rock salt as quarried is of a brownish colour, from an admixture of earthy matters, from which it is freed by solution and crystalization. The expense of sinking a shaft and quarrying the solid salt may be avoided by boring down to the bed with a pipe a few inches in diameter, and letting water flow through it upon the salt; the strong solution of salt thus produced may be pumped up and evaporated. On the sea-coasts of Portugal and the south of France, and of other warm countries, salt is procured by the evaporation of sea-water. On the flowing of the tide the water is allowed to pass into shallow basins, and as the concentration proceeds under the influence of the sun's rays, it is transferred from one basin to another, and, finally, crystals are formed by the application of artificial heat. If the sea-water were evaporated to dryness its other saline constituents would become mixed with the chloride of sodium. Sea-water generally consists of

Chloride of sodium .	2·50	in 100 parts.
Chloride of magnesium	0·35	
Sulphate of magnesia	0·58	
Carbonate of lime and Carbonate of magnesia	0·02	
Sulphate of lime . .	0·01	
Water	96·54	

Traces of iodide and bromide of magnesium also exist. The liquor which remains after the common salt has crystalized out of sea-water is called bittern, and as it contains sulphate of magnesia it is preserved for the manufacture of Epsom salts. The chloride of sodium crystalizes in cubes; it is equally soluble in water at all temperatures, 100 parts of water dissolving 36·5 of the salt; by a strong heat it may be converted into vapour; its crystals are anhydrous, but generally have fissures containing water, which, when heated, produces decrepitation by bursting the crystal. The ordinary uses of this compound are too well known to need mention; it is now the source whence all the other salts of soda, such as the carbonate and sulphate, are derived; it is employed in the manufacture of glass and of porcelain, and is used as a manure.

Sulphate of soda (Na O. SO_3. + 10 HO.), called *Glauber's salt,* after its discoverer, exists in some mineral springs, and may be prepared by decomposing carbonate of soda with dilute sulphuric acid; it is manufactured in large quantities from common salt in the process for obtaining muriatic acid. Sulphate of soda crystalizes in six-sided prisms, very much channeled at the sides; it is very soluble in water; its crystals contain 56 per cent. of water, which they lose by exposure to air, and fall into a white powder.

Nitrate of soda—cubic nitre ($Na\ O.\ NO_5.$).—This salt is found on the surface of the earth in South America; it may be prepared by acting upon carbonate of soda with nitric acid; it crystalizes in rhombs, is very soluble in water, and slightly deliquescent; it is used in the manufacture of nitric and sulphuric acids, and as a manure.

Hyposulphite of soda ($Na\ O.\ S_2.\ O_2. + 10\ HO.$) may be obtained by boiling together three parts of dry carbonate of soda with one of sulphur, until the latter is dissolved, and passing a stream of sulphurous acid gas through the liquor, until it smells strongly of it. The salt may be produced more simply, by boiling three parts of carbonate of soda with two of sulphur, and exposing the deep-yellow liquor to the air, until it yields a colourless liquor on filtration. This salt is easily soluble in water, and has acquired some importance from its use in photography, being employed to dissolve out the sensitive silver compounds.

Hypochlorite of soda—chloride of soda, or disinfecting liquor of Labaraque, is prepared by passing chlorine into a solution of carbonate of soda as long as any will be absorbed; the liquor then contains hypochlorite of soda, chloride of sodium, and bicarbonate of potash; no carbonic acid is evolved.

Tribasic phosphate of soda is prepared by decomposing a solution of phosphate of lime obtained from bones; by carbonate of soda, carbonate of lime and phosphate of soda are formed. This salt crystalizes in oblique rhombic prisms; it is easily soluble in water, and has an alkaline reaction; when exposed to the air the crystals lose some of their water, but retain their form; it consists of one atom of phosphoric acid, two of soda, one of basic water, and twenty-four of water of crystalization; it gives with nitrate of silver a yellow precipitate of phosphate of silver. *Bibasic phosphate of soda* is formed by fusing the common phosphate: at a moderate heat all the water of crystalization is given off, and at a red heat the basic atom of water is expelled; when the salt is redissolved it does not combine with basic water, but unites with soda only. This salt was called *pyrophosphate;* it gives a white precipitate with nitrate of silver. *Monobasic phosphate of soda* is obtained by heating the tribasic or bibasic phosphate to redness; the acid remains combined with one atom of soda after the volatile base is expelled; the salt fuses into a glass and does not crystalize; and throws down from solutions of lead and silver precipitates which consist of a soft tenacious paste.

Borate of soda ($Na\ O. + 2\ BO_3. + 10\ HO.$).—Boracic acid forms various salts with soda, of which the *biborate* or *borax* of commerce is the most important; it consists of $Na\ O. + 2\ BO_3. + HO.$, and is found in the water of certain lakes in Thibet, China, and in Hungary, whence it was imported in the shape of small crystals smeared with fatty matter, and called *tinkal.* Borax is now procured by treating native boracic acid, brought from Tuscany, by carbonate of soda; its crystals are oblique rhombic prisms; the salt, though containing two atoms of acid, has an alkaline reaction; when heated it froths up very much, and releases its water; it is used in experiments with the blow-pipe, as it dissolves most metallic oxides readily, and enables the metals to produce the coloured glasses peculiar to them; it is employed also in the manufacture of glass and porcelain. The other borates of soda are unimportant.

Chloride of barium ($Ba\ Cl. + 2\ HO.$) may be prepared by acting upon native carbonate of barytes with dilute muriatic acid, or by decomposing sulphuret of barium with dilute muriatic acid; the salt crystalizes from a hot solution in rhomboidal tables.

Sulphate of barytes ($Ba\ O.\ SO_3.$) exists native in great abundance, generally associated with sulphuret of lead. This salt is insoluble in water; its crystal is an oblique rhombic prism, generally very flat; it is called *heavy spar,* and *terra ponderosa,* and is one of the heaviest saline bodies; reduced to fine powder it is used as a substitute for white lead in painting; it may be prepared by adding sulphuric acid to any solution containing barytes.

Nitrate of barytes may be obtained by acting upon carbonate of barytes with dilute nitric acid, or by mixing strong hot solutions of sulphuret of barium and nitrate of soda.

Nitrate of strontia crystalizes in octohedrons, and during the formation of the crystals bright flashes of light are emitted.

Chloride of calcium ($Ca\,Cl. + 6\,HO.$) may be prepared by acting upon carbonate of lime with muriatic acid; but it is abundantly furnished as the residue in preparing carbonic acid, &c. It is very soluble in water; the solution when evaporated yielding long striated rhombic prisms, which are very deliquescent, undergo watery fusion when heated, and, giving off two-thirds of their water of crystalization, form a powder which is employed in making freezing mixtures; at a red heat it fuses and becomes anhydrous; in this state it phosphoresces in the dark, and constitutes Homberg's pyrophorus; it has a powerful affinity for water, uniting with two atoms of it with evolution of much heat, and is therefore employed to dry gases and to abstract water from liquids, such as spirits of wine.

Fluoride of calcium—fluor spar ($Ca\,F.$) exists abundantly, crystalized in cubes and octohedrons, but chiefly in masses. It is soft and tough to a certain extent, when first taken from the earth, and may be cut into ornaments remarkable for a variety of colours; its crystals phosphoresce by heat or electricity; it is insoluble in water; all the other preparations of fluorine are derived from it; from its forming very fusible compounds with silicious and aluminous minerals, it is used as a flux in smelting metallic ores, and is hence called fluor spar.

Sulphate of lime ($Ca\,O.\,SO_3. + 2\,HO.$) may be prepared by mixing any soluble salt of lime with sulphuric acid; it forms in this way a crystaline powder, requiring 461 parts of water, hot or cold, for its solution. This salt is found in abundance either in distinct colourless crystals, or in semi-transparent crystaline masses, constituting *alabaster;* or in masses having no definite shape, and forming extensive rocky beds, in which condition it is called *gypsum.* From this last form *plaster of Paris* is obtained by calcining the gypsum broken into small pieces, at a heat below 300°, until the water of crystalization is driven off; a powder is produced which must be kept in air-tight vessels; when mixed with water it rapidly re-combines with it, evolving heat and expanding as it solidifies, so as to fill the crevices in any mould into which it may be poured. On this principle is based the art of casting plaster, and of making *stucco;* solutions of glue or of earthy salts being used in place of water.

Phosphoric acid forms various salts with lime, the most important of which is that phosphate which constitutes the *earth of bones;* this is a tribasic prosphate; its formula is $8\ Ca\ O + 3\ PO_5$. : mixed with small quanties of carbonate and sulphate of lime, and of fluoride of calcium, it forms the inorganic part of the skeleton of mammals; it is precipitated by dissolving bone earth in muriatic acid, and then neutralizing the solution with caustic ammonia; thus procured it is a gelatinous powder united with four atoms of water.

Hypochlorite of lime—chloride of lime—bleaching salt.—This substance is prepared on a large scale by exposing hydrate of lime to the action of chlorine, in an apparatus constructed for the purpose. One hundred parts of slaked lime combine with from 50 to 60 of chlorine; if the process be too rapidly conducted chlorate of lime and chlorate of calcium are formed, which may be known by the product becoming damp when exposed to the air. The best bleaching powder thus prepared does not contain more than 40 per cent. of chlorine; but if lime diffused through water, so as to form a thin cream, be exposed to the action of chlorine, it will absorb more than its own weight of gas, and be entirely dissolved. The best bleaching powder contains about 18 per cent. of hydrate of lime in excess, which remains undissolved when the powder is treated with water. The bleaching powder of commerce does not generally contain more than 30 per cent. of chlorine. The solution of chloride of lime has an alkaline reaction, and is destitute of bleaching properties if no acid be present, as the acid releases the chlorine which then acts upon the colouring matter. A difference of opinion exists as to the precise constitution of bleaching powder; one view being, that there is a direct combination between the chlorine and the lime, forming chloride of oxide of lime; and another, that a double salt of a hypochlorite with a chloride exists in the compounds.

Chloride of magnesium ($Mg. Cl.$) may be obtained by acting on carbonate of magnesia with muriatic acid; by evaporating the solution very deliquescent prisms are procured with six atoms of water. This salt is found in sea-water.

Sulphate of magnesia ($Mg\ O.\ SO_3.$) is found in abundance in the saline mineral springs of Seidlitz, Seltzers, Epsom, &c.; it is commonly known under the name of Epsom salts. It is principally obtained from magnesian limestone, by calcining and then treating it with dilute sulphuric acid; sulphate of lime being sparingly soluble, is easily separated from the sulphate of magnesia, which is washed out and crystalized. Sulphate of magnesia is also obtained by the action of sulphuric acid from the liquor which remains after the crystalization of common salt from sea-water. This salt crystalizes in right rhombic prisms, containing seven atoms of water, one being constitutional, the other six of crystalization; when heated to 212° it gives off the six atoms of water of crystalization, retaining the seventh even at a heat of 400°; it forms with the sulphate of potash a double salt.

Nitrate of magnesia ($Mg\ O.\ NO_5.$) is a very soluble deliquescent salt, and cannot be obtained dry. *Borate of magnesia* constitutes the mineral boracite.

A variety of *silicates of magnesia* exist native: one of these is the *steatite or soapstone;* another is the *meershaum,* from which bowls of tobacco-pipes are cut; *olivine* and *serpentine,* which are found in certain kinds of marble, are also simple silicates of magnesia; *amphibole* and *pyroxene* are double silicates of magnesia and lime, with an admixture of protoxide of iron.

Chloride of aluminum ($Al_2.Cl_3.$) may be obtained in a hydrated form by dissolving alumina in muriatic acid. *Fluoride of aluminum* is found native. The *topaz* is a double fluoride and silicate of alumina.

Sulphate of alumina ($Al_2.O_3. + 3\ SO_3. + 18\ HO.$) is prepared by dissolving alumina in dilute sulphuric acid; it has a sweetish styptic taste, is very soluble in water, and crystalizes on thin flexible plates. When heated to redness this salt gives off its water and acid, pure alumina remaining. $SO_3.$ unites with alumina in another proportion, forming the mineral *aluminite.* Sulphate of alumina combines with the alkaline sulphate to form the double salts called *alums.* Of these, the most important is the *double sulphate of alumina and potash,* or common alum; the formula of which is $KO.\ SO_3. + Al_2.O_3. + 3\ SO_3. + 24\ HO.$ Alum is manufactured on a large scale for the purposes of commerce. The material from which it is derived is a clay-slate found in coal districts under the beds of good coal; this clay-slate contains a certain quantity of coal mixed with an abundance of bisulphuret of iron. When exposed to the air the sulphuret rapidly absorbs oxygen and forms sulphate of iron, with an excess of acid, which reacts upon the clay with the alumina of which it combines; this effect is hastened by the application of heat, which is applied by placing fuel under the mineral, built up into pyramidal heaps, with channels through the interior to keep up a draught; the slate contains coal enough after the fuel beneath has been ignited; the mass becomes brick-red as it burns; as the process goes on quantities of material are added till the heap acquires a height of from 60 to 80 feet. When the calcined mass is cooled it is reduced to powder, and treated with water. Sulphate of alumina and sulphate of iron dissolve out, and the liquor is evaporated to a certain strength; a solution of some salt of potash is then added, generally the waste chloride of potassium from soap-boilers; this decomposes the sulphate of iron, forming sulphate of potash, which unites with the sulphate of alumina, and crystalizes out as alum, the iron remaining as a chloride in solution. In some volcanic countries a mineral is found containing potash and sulphuric acid united to alumina; from this *rock alum* is obtained, which is held in high estimation by dyers, as it contains no trace of sulphate of iron, which affects the colours of the dyes. Alum forms regular octohedral crystals, the solid angles being often replaced by the surfaces of a cube; when heated its water is first expelled, and at a red heat most of its acid is driven off, sulphate of potash and pure alumina remaining; it has a sweetish astringent taste, an acid reaction, and is soluble in 18·4 parts of cold water. The pyrophorus of Homberg is prepared from alum; three parts of dried alum and one of lampblack well mixed, are placed in a stout glass bottle, and being bedded with sand in a crucible, and carefully heated to redness until a blue flame appears at the mouth of the bottle; when this has lasted a few minutes, the bottle is stoppered with a piece of chalk, and the whole cautiously cooled. The black powder found in the bottle is a mixture of lampblack, alumina, and sulphuret of potash, which last, being in very minute division, takes fire, and emits considerable light when a little of the powder is shaken out of the bottle.

Basic or cubical alum, which is preferred as a mordant to common alum, is prepared by adding carbonate of potash to a solution of alum; it has no acid reaction, and crystalizes in cubes.

A remarkable mineral called *wavellete*, found in the counties of Cork and Tipperary in Ireland, is a phosphate of alumina.

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[illegible] is formed [illegible] acid, hydrogen [illegible] green [illegible] crystals of hydrated chloride; the solution absorbs oxygen from the air rapidly, and its colour is changed to a dark green; the crystals if heated without access of air give a white mass of protochloride, and in the air perchloride is produced.

Sesquichloride of iron ($Fe_2. Cl_3.$) is formed when iron is dissolved in a mixture of nitric and muriatic acids; a deep-brown solution is formed, which, on evaporation, yields large red, very deliquescent crystals of hydrated chloride; this salt is decomposed by heat, muriatic acid is given off, and red oxide of iron remains, with some chloride.

Proto-iodide of iron (Fe. I.) is formed by digesting iodine in water, with an excess of iron filings; a colourless solution is obtained which yields a crystaline mass upon evaporation, and absorbs oxygen rapidly; it dissolves iodine largely, becoming brown, probably containing sesqui-iodide ($Fe_2. I_3.$) and free iodine.

Protosulphate of iron, green copperas ($Fe O. SO_3. + 7 HO.$) is manufactured on a large scale by exposing to the action of air and moisture the bisulphuret of iron found in alum clay-slate; oxygen is absorbed rapidly, sulphuric acid and oxide of iron are formed; the liquor containing these is conducted into tanks, where it is brought into contact with pieces of old iron, which neutralize the excess of acid produced by the bisulphuret, and preserve the iron in a state of protoxide; the salt is obtained by evaporating the solution. This salt may be prepared in a small way by acting upon iron-wire or filings with dilute sulphuric acid. The crystals generally contain seven atoms of water, one of these being constitutional; the shape of the crystal is a short oblique rhombic prism, with many secondary faces. The taste of the salt is styptic and metallic; it is very soluble in water, and very sparingly in alcohol; when heated it gives off water, and at a full red heat its $SO_3.$, a portion of which is resolved into sulphurous acid and oxygen, by which the iron is peroxidized; this peroxide is called *rouge* and *colcothar*, and is employed as a polishing material. The protosulphate even when dry absorbs oxygen, and becomes covered with a reddish brown crust of persulphate, hence its name of *copperas*.

Sesquisulphate of iron ($Fe_2. O_3. + 3 SO_3.$) is found native, and may be prepared by treating red oxide of iron with oil of vitriol, and applying moderate heat to expel excess of acid; a red solution is formed with water, which, when evaporated, yields a deliquescent mass; this salt is decomposed by a strong heat. There are several basic persulphates of iron, of which the most important is the rust-coloured powder, thrown down from a solution of protosulphate of iron when oxidized by exposure to air.

Protonitrate of iron may be formed by dissolving sulphuret of iron in cold dilute nitric acid. Metallic iron dissolves in dilute nitric acid without evolution of hydrogen; water and nitric acid are decomposed, and oxide of iron and ammonia are formed. *Pernitrate of iron* is produced when iron is dissolved in hot nitric acid.

Protophosphate of iron is formed by decomposing a solution of protosulphate of iron with phosphate of soda; it is a white powder which becomes blue upon exposure to the air; this salt exists native, forming the *bog iron ore*. *Sesquiphosphate of iron* is produced by decomposing solution of sesquisulphate of iron by phosphate of soda. Both these phosphates are used in medicine. The salts of protoxide of iron absorb nitric oxide in considerable quantity, and form with it a deep olive coloured liquor, which rapidly attracts oxygen from the air.

Chloride of nickel (Ni. Cl.), is obtained by dissolving oxide of nickel in dilute muriatic acid, or by acting on nickel with hot concentrated acid; it forms emerald green rhombic crystals; when heated these abandon their water and form a yellow powder, which, by a red heat, sublimes in crystals resembling mosaic gold.

Chloride of zinc (Zn. Cl.), is prepared by burning metallic zinc in chlorine, or by dissolving the metal in muriatic acid; the solution is colourless; on evaporation it yields rhombic crystals, which are very deliquescent, and contain water; the dry salt is white, and melts above 212°; it was formerly called, from its softness and fusibility, *butter of zinc;* its great affinity for water renders it a powerful caustic when applied to any part of the living body; chloride of zinc is the basis of Sir William Burnett's preservative against decay in the timbers and cordage of ships.

Sulphate of zinc ($Zn\ O.\ SO_3. + 7\ HO.$) may be prepared by dissolving the metal in dilute sulphuric acid, and on the large scale is produced by roasting native sulphuret of zinc in a current of hot air in a reverberatory furnace; the metal and sulphur attract oxygen, and a neutral sulphate of zinc is formed, which is dissolved in water, and crystalized by evaporation. The sulphate is sometimes formed by exposing the sulphuret to the action of air and moisture, by which the salt is gradually formed: the first crystals produced are run into moulds after undergoing watery fusion, and, when solidified, the mass is called *white vitriol.* Sulphate of zinc forms right-rhombic prisms in crystalizing; these contain 43·9 per cent. of water, are permanent in the air, and dissolve in 2½ times their weight of cold water.

Protochloride of tin ($Sn\ Cl. + 3\ HO.$) is obtained anhydrous by treating tin in a current of muriatic-acid gas, hydrogen being evolved; or, by distilling a mixture of equal parts of tin and corrosive sublimate in a glass retort, metallic mercury first passes over, and protochloride of tin sublimes at a strong red heat, under the name of *salt of tin:* the crystalized protochloride is extensively used as a mordant in dyeing. This salt has a strong affinity for oxygen and chlorine; by this property it reduces salts of silver, mercury, and gold to the metallic state; with indigo and other organic dyes it forms colourless compounds.

Perchloride of tin ($Sn.\ Cl_2.$) is obtained anhydrous by distilling a mixture of four parts of corrosive sublimate and one of tin; a colourless liquid distils over, which forms dense white fumes when in contact with air; this is the bichloride, and was called the *fuming liquor of Libavius;* mixed with half its weight of water it forms a crystaline mass, and boils at 248°.

Protosulphate of tin is formed by acting on tin with strong oil of vitriol.

Bancroft's mordant is made by digesting two parts of tin with three of strong muriatic acid for an hour, and then cautiously adding one and a half parts of oil of vitriol; the tin is dissolved, and the solution, on cooling, forms a crystaline mass, which is dissolved in water, in the proportion of one part of tin in eight of the solution.

Chlorocarbonic acid ($Cr.\ Cl_3. + 2\ Cr.\ O_3.$) is prepared by melting in a crucible 10 parts of common salt and 17 of bichromate of potash; the melted mass is to be poured upon a slab and broken into small pieces, and being placed in a retort, 40 parts of oil of vitriol are to be added; the entire distils over in a few minutes without the application of heat; this compound is a thin blood-red liquid, black by reflected light; on exposure to air it gives off copious red fumes like nitrous acid; alcohol or phosphorus placed in contact with it burns with a bright flame; it is decomposed by water.

Bichromate of potash ($KO. + 2\ Cr.\ O_3.$) is prepared from *chrome iron* ($Fe.\ O. + Cr_2.\ O_3.$) by exposing a mixture of the ore with saltpetre to an intense heat in a furnace for some hours. The salt crystalizes after a process of lixiviation in large four-sided prisms and square tables of a rich orange-red colour; it melts easily, and, on cooling, forms different crystals; and is soluble in ten parts of cold water.

Arsenious acid is dissolved largely by the caustic and carbonated alkalies, but the salts cannot be obtained in crystals, and their characters have not been defined with certainty. Arseniates of iron, nickel, &c., are formed, as also iodide and chloride of arsenic; this metal combines with sulphur to form a sulphur acid, which forms sulpho-arseniates with bases.

Sesquichloride of antimony ($Sb. A_3.$).—This salt is prepared pure by distilling from a hard glass retort a mixture of equal weights of sulphuret of antimony, in fine powder and corrosive sublimate; the chloride distils over with a gentle heat as an oily liquid, which solidifies into a white crystaline mass; it is very deliquescent, and becomes soft on exposure to air, hence called *butter of antimony.* If this salt be mixed with much water both are decomposed; a white oxychloride is precipitated which is called *powder of Algarotti,* from its discoverer.

Antimonial powder — James's powder. — This once highly-esteemed nostrum is prepared by calcining equal parts of sulphuret of antimony and hartshorn shavings, in an iron pot, at a dull red heat, until the mass becomes ash-grey; it is then exposed to a white heat for two hours in a loosely-covered crucible; the mass becomes white and is reduced to powder. In the process sulphur and the carbon and hydrogen of the hartshorn are burned away, and the antimony is converted into antimonious acid, of which a small quantity unites with the lime of the bone, the rest of the lime remains as phosphate mixed with the antimonite of lime and antimonious acid. The composition of this powder varies very much; it seldom contains more than one per cent. of antimonite of lime, and this, the only soluble and active ingredient, is removed if the powder has been washed: it is a mere mechanical mixture of its constituents.

Chloride of copper—blue vitriol ($Cu. Cl.$) is prepared by dissolving copper in *aqua regia,* or oxide of copper in muriatic acid; by the action of an alkali on a solution of the chloride the pigment called *Brunswick green* is produced; it is an oxychloride of copper.

Sulphate of copper ($Cu\ O.\ SO_3.\ HO + 4\ HO.$) is prepared on the large scale by treating native sulphuret of copper in the same manner as the sulphurets of iron and zinc; it may be prepared by acting upon the metal with boiling oil of vitriol, or with dilute sulphuric acid to which some nitric acid has been added. It crystalizes in large double oblique rhombs of a fine blue colour, which are soluble in four parts of cold and two of boiling water. The crystals contain five atoms of water, of which one is constitutional.

Nitrate of copper ($Cu\ O.\ NO_5 + 3\ HO$) is obtained by dissolving copper in dilute nitric acid; the salt crystalizes in oblique rhombs of a rich blue colour, and, sometimes, in paler rhomboidal plates which contain six atoms of water; it deflagrates violently when thrown on burning coals, or when struck on an anvil with a little phosphorus. If some of the salt be wrapped up tight in tin foil it becomes very hot, swells, fumes, and oxidizes the tin so rapidly, that in some points brilliant sparks are thrown out.

Arsenite of copper ($HO.\ 2\ Cu.\ O. + As.\ O_3.$) is obtained by the decomposition of arsenite of potash and sulphate of copper; it is a fine apple-green powder, and constitutes the pigment named *Schules green.* A more beautiful pigment, known under the name of *Schweinfurt green,* or *Emerald green,* is a compound of acetate of copper and arsenite of copper.

Iodide of lead, ($Pb.\ I.$) is formed by adding iodide of potassium to a solution of nitrate of lead; the precipitate is of a bright lemon-yellow colour, soluble in 1235 parts of cold and 194 of boiling water; the solution is colourless, and, on cooling, deposits bright gold-coloured six-sided plates.

Sulphate of lead ($Pb\ O.\ SO_3.$) is found in the mineral kingdom in large transparent rhombs, isomorphous with sulphate of barytes; it may be procured by adding sulphuric acid, or sulphate, to any solution of lead; it is soluble in strong acids.

Nitrate of lead is obtained by dissolving lead in dilute nitric acid, and evaporating the solution. *Phosphate of* *lead* is formed by the action of phosphate of soda on a solution of nitrate of lead.

Chromate of lead—chrome yellow ($Pb\ O.\ Cr.\ O_3.$) is formed by mixing solutions of nitrate of lead and bichromate of potash; the precipitate is a fine lemon-yellow powder, insoluble in water; it is found native in ruby-red crystals constituting *red lead ore.* This salt is much used as a pigment, and is made on a large scale; in commerce it is found of various shades of yellow and orange, consisting of a mixture of neutral and basic chromates. Basic chromate is of a bright vermilion colour, and is called chrome red.

Nitrate of bismuth ($Bi_2.\ O_3.\ + 3\ NO_5.\ + 9\ HO.$) is formed by dissolving the metal in dilute nitric acid; rhomboidal crystals are formed on evaporation and cooling; these deliquesce. This salt is decomposed by water, and forms, according to circumstances, one or other of two basic salts; these subnitrates are employed in medicine, and are used indiscriminately; one is formed by decomposing the crystals without excess of acid, and the other by acting on them with excess of acid; both yield very nearly the same amount of oxide.

Chloride of silver ($Ag.\ Cl.$) exists as a native ore of silver, called *horn-silver;* it may be formed by mixing a solution of common salt with a soluble salt of silver, by which a curdy white precipitate is formed, insoluble in water and acids, but soluble in water of ammonia; it fuses below redness and forms a horny mass, whence its old name. Recently precipitated, it is exceedingly sensible to the action of light, and, on exposure to the sun's rays, becomes pink, violet, and, finally, black; to effect this change organic matter or water must be present, with the hydrogen of which the chlorine combines, and a thin layer of suboxide, or of metal, is formed. The properties of this salt in relation to light are of great importance in photography.

Iodide of silver ($Ag.\ I.$) is obtained by decomposing a soluble salt of silver by iodide of potassium; a primroseyellow precipitate is formed, insoluble in water, and nearly insoluble in strong water of ammonia; it is easily fusible, becoming opaque on cooling. In certain conditions this salt is more sensitive than the chloride, and is the basis of Daguerre's photographic process.

Hyposulphite of silver (2 Ag. O. $+$ S_2. O_2.) is prepared by decomposing a neutral solution of nitrate of silver by a solution of hyposulphite of soda; a white precipitate is formed which is soon changed into black. The solution of this salt is extremely sweet. A solution of hyphosulphurous acid forms with chloride of silver an intensely sweet solution, and the alkaline and earthy hyposulphites dissolve most of the salts of silver, forming double salts of exceedingly sweet taste.

Nitrate of silver (Ag O. NO_5.) is prepared by dissolving granulated silver, or silver in small fragments, in dilute nitric acid. At first, no gas is evolved, as the nitric acid dissolves the nitric oxide formed, but copious red fumes are disengaged towards the end of the process. By evaporation and cooling the salt is made to crystalize in colourless rhomboidal plates, often four inches across; these are anhydrous. The salt is soluble in its own weight of cold water: heated to about 450° it melts into a colourless liquid, which, poured into silver moulds, forms, when congealed, the *lunar caustic* used as an escharotic by surgeons. The fused salt should be snow-white; it is not affected by light, unless organic matter be present, when it becomes black, silver being reduced; whence its use as a marking ink and hair-dye. It yields its oxygen readily to combustible bodies; if a few grains of it be placed on an anvil with a bit of phosphorus, and struck with a hammer, it will explode; it is reduced to the metallic state from its solutions by all deoxidizing agents.

Chloride of mercury—Corrosive sublimate (Hg. Cl.) may be prepared by dissolving red oxide of mercury in muriatic acid, and evaporating; the salt crystalizes in long right-rhombic prisms generally opaque. The corrosive sublimate is generally prepared by the dry way, the basis of which is, exposing to a red heat in a retort, equal weights of sulphate of mercury and common salt; the chlorine of the common salt is sublimed in combination with the mercury, whilst the oxygen and acid unite with the sodium; chloride of mercury and sulphate of soda being formed. The sublimed chloride crystalizes in right-rhombic prisms; its sp. gr. is 5·4; it melts at 509°; it is soluble in two parts of boiling and in twenty of cold water; it is soluble in $2\frac{1}{3}$ parts of cold alcohol and in three parts of cold ether; it dissolves more readily in muriatic acid and solutions of the alkaline chlorides than in water; with these it forms very soluble double salts, of which the double chloride of mercury and ammonium is used in pharmacy.

Subchloride of mercury—calomel (Hg. Cl.) may be prepared either by precipitation or by sublimation. By the first process nine parts of mercury are to be digested in eight parts of nitric acid of sp. gr. 1·25, without heat, until no more mercury appears to dissolve, and the liquor begins to assume a yellow colour. To this solution is added one containing eight parts of common salt, dissolved in 250 parts of boiling water, to which a little muriatic acid may be added; when the solutions are mixed the calomel precipitates. Nitrate of the suboxide of mercury is formed by the solution of the metal in the acid, and upon the addition of the chloride of sodium nitrate of soda and subchloride of mercury are formed. Sublimed calomel is prepared by rubbing four parts of corrosive sublimate and three parts of metallic mercury together until no trace of the metal shall be seen; the mixture is to be then sublimed by exposing it to heat in an earthen pot to which a glass head is fitted. Sublimed calomel may be prepared by a different process. The sublimation must be repeated to complete the decomposition, and as the mass always contains some undecomposed chloride, it must be carefully levigated and washed with boiling water; the washings are to be repeated as long as the liquor turns milky on the addition of water of ammonia. The precipitated calomel is a pure white powder; the sublimed a crystaline mass whose primitive form is a square prism. Calomel is insoluble in water. The sublimed calomel may be obtained in a state of very minute division by conducting its vapour into a vessel containing boiling water, by the vapour of which the calomel is condensed and falls into a very fine powder. The presence of sublimate may be detected by boiling the calomel for a few minutes in alcohol, and adding a few drops of water of ammonia; a white precipitate is formed if sublimate be present. Calomel is converted into sublimate and mercury by boiling it with muriatic acid, or with solution of common salt, or sal ammoniac.

Iodide of mercury ($Hg.\ I.$). Red iodide may be formed by triturating mercury and iodine with a few drops of alcohol; this compound is dark red, but it may be obtained of a brilliant red colour by precipitating a solution of corrosive sublimate with an equivalent of iodide of potassium.

Sesqui-iodide of mercury, or yellow iodide ($Hg_4.\ I_3.$) is prepared by decomposing a solution of iodide of potassium, to which half as much iodine as it already contained has been added by a slight excess of the solution of subnitrate of mercury; the precipitate is a bright yellow powder which, having been cautiously dried with little exposure to light, is employed in pharmacy.

Sulphate of mercury ($Hg\ O.\ SO_3.$) is prepared by boiling oil of vitriol on mercury until it is converted into a white saline mass, from which excess of acid is expelled by heating it to redness. The salt is a white powder which, by a large quantity of water, is resolved into free acid and a basic sulphate known by the name of *turpeth mineral.*

Perchloride of gold ($Au.\ Cl_3.$) is formed by dissolving gold in *aqua regia,* and evaporating cautiously to dryness; the salt is obtained as a ruby-red crystaline mass; its solution in water is yellowish red, acid, and is decomposed by the light. It is soluble in alcohol and ether, from which last it is deposited in the metallic state upon evaporation, and in this way gilding on steel and on some other surfaces is effected. *Subchloride of gold* (Au. Cl.) is prepared by heating the chloride to to about 450°, in a porcelain dish, and stirring it very carefully until no more chlorine is given off; a yellowish-white mass remains, insoluble in water, by which it is gradually resolved into chloride and metallic gold. A chloride solution of gold free from excess of acid can be procured only in this way. In a photographic process, discovered by Sir John Herschell, a neutral solution of chloride of gold is employed as the sensitive compound, and the process is accordingly named the *chrysotype*.

CHEMISTRY OF ORGANIC BODIES.

THE composition of organic bodies is generally much more complex than that of mineral substances. There is only one instance of an atom of an organic compound containing but two simple atoms; and carbonic acid and cyanogen are the only examples of an organic atom being constituted by three simple atoms. The number of atoms which forms an organic body is sometimes very great; thus, an atom of albumen is composed of 883 simple atoms, and an atom of spermaceti comprehends 468 simple atoms. Notwithstanding the immense number and great variety of organic products, the animal and vegetable kingdom may be said almost entirely to consist of six elements; of these, sulphur and phosphorus are rare; nitrogen exists more extensively, in animal substances especially; oxygen and hydrogen are found in nearly all, and carbon is a constituent of all bodies animal and vegetable. There are many elements, however, which, though not actually entering into the composition of organic bodies, are found intimately associated with them, and perform important functions in relation to them. Iodine and bromine are found in many marine plants and sponges; in most animal and vegetable juices common salt and oxygen salts of potash, soda, lime, and magnesia exist; the bony skeleton of one race of animals is composed of phosphate of lime; carbonate of lime constitutes the testaceous covering of another section of the animal kingdom; and the rudimentary skeleton of the lower species of zoophytes is formed of silica. Iron is an essential element of the red colouring matter of the blood; it is also found in other parts of the animal tissues; and in the bones and teeth traces of fluorine and silica are found. These elements, however, save in the case of the iron in the colouring matter of the blood cannot be said to possess vitality, as they exist in an inorganic state, either held in solution by the animal fluids or deposited in a solid shape.

Organic bodies may be divided into three primary classes: the first of these comprises the organised elements of the living structure, which, by the function of life, are enabled to create from certain nutritious juices elements similar to themselves. The exact relations of these elements to each other we are unable to determine, as they are not regulated by the laws of ordinary affinity. By the conjoint vital action of these elements bodies of the second class are produced: thus, from water, carbonic acid, and air, the vital action of plants secretes sugar, starch, and albumen. The third class of organic bodies comprises those produced by the decomposition, spontaneous or artificial, of the former two; thus sugar, by fermentation, yields alcohol and carbonic acid; and woody fibre when heated to a certain extent produces a number of organic compounds.

Compounds of nitrogen and hydrogen.—The properties of carbon, the most general organic element, have been already discussed. The compound of nitrogen and hydrogen called *ammonia*, or the *volatile alkali*, ranks next in importance; it is produced in nearly every reaction when the gases are brought together. When an electric spark is passed through damp air, nitric acid and ammonia are formed; ammonia is evolved in large quantities by the decomposition of organic matter containing nitrogen, and when they are distilled at a high temperature; it is contained in the sweat of animals, is exhaled by the flowers of many plants, and by the leaves of cruciferous plants. For chemical purposes it is obtained from the muriate of ammonia or sal-ammoniac, which is manufactured in large quantities for commercial purposes. A mixture of equal parts of sal-ammoniac and slacked lime is heated in a flask, and the gas evolved is to be passed through a tube containing dry lime or fused potash (by which any moisture is absorbed), and then collected over mercury. Ammonia is colourless and transparent: its odour is strong, pungent, and irritating, being the well-known smell of hartshorn; when dry it has no action on vegetable colours, but if moisture be present, its reaction is powerfully alkaline; the brown colour imparted by it to turmeric paper is discharged by heat, which distinguishes it from the colour given by the fixed alkalies or earths; it is liquefied by a pressure of 6½ atmospheres, or at a temperature of — 61°; it is caustic and poisonous when inspired. Ammonia is slightly combustible, but does not support combustion; it is decomposed by passing a series of electric sparks through some of the gas confined over mercury, and is resolved into three volumes of hydrogen and one of nitrogen; its fonnula, therefore, is NH_3; it may be decomposed in a variety of ways. Water at 32° takes up 780 times its volume of ammonia; great heat is evolved during the absorption; and the solution, which is increased two-thirds in volume, has a sp. gr. of 0·872, and boils at 120°; it holds about 32 per cent. of ammonia, and is called *water of ammonia,* and incorrectly *liquid ammonia;* for ordinary purposes this fluid need not contain more than 18 per cent. of gas; its sp. gr. is then 0·930. The water of ammonia possesses, in an eminent degree, all the characters of the gases: it neutralizes the strongest acids, and as a base ranks next to lime: its action on chlorine is violent and accompanied by flame, sal-ammoniac being formed and nitrogen set free. Free ammonia is recognised by its odour, by its evanescent stain upon turmeric paper, and its forming dense white fumes on the approach of a glass rod moistened with strong muriatic acid; all substances which contain it are either volatilized by heat or decomposed, the ammonia being liberated; in all cases, by heating the substance with moist caustic potash, ammonia is evolved. The most remarkable property of ammonia is, that in acting on metallic compounds, and on certain organic acids, it abandons an atom of hydrogen, and the remaining NH_2. combines with the metal or with the acid. From this fact Dr. Kane concluded, that NH_2. should be regarded as the radical of ammonia, and named it *amidogene* (Ad.). Ammonia is therefore an *amidide of hydrogen*, and is thus assimilated in constitution to chloride of hydrogen. This view has been almost unanimously adopted.

Ammonia and chlorine.—By inverting a bottle-full of chlorine gas over a cup containing solution of sulphate or muriate of ammonia, the gas will be gradually absorbed, and a heavy yellow liquid will collect in globules in the bottom of the cup. The utmost caution must be used in manipulating this substance. If it be strongly rubbed, or struck, or touched with any greasy body or with phosphorus, it explodes with tremendous violence; a globule of about the size of a pin's head, exploded in a teacup, will shatter it to pieces. Sir H. Davy found that, when decomposed over mercury, it gives nitrogen and chlorine in the proportion of one to three, and hence it was pronounced *chloride of nitrogen*, under which name it is described in most of the books: traces of sal-ammoniac, however, are found when it is decomposed, and it must consequently contain hydrogen.

Iodine and ammonia form a compound so explosive, that when rubbed, even under water, it detonates; and by the action of ammonia on metallic oxides a numerous class of bodies may be formed, all of which possess detonating properties. The most violent of these compounds is *ammoniuret of silver*, prepared by digesting recently prepared oxide of silver in water of ammonia, or by dissolving nitrate of silver in an excess of water of ammonia, and precipitating the solution by caustic potash; it is a brown powder, which detonates violently on the slightest friction or shock; when exploded it is said to produce water, nitrogen, and metallic silver. *Ammoniuret of gold* is produced by the action of water of ammonia on peroxide of gold; it is a brown powder nearly as explosive as the former one. These compounds are called *fulminating silver* or *gold.*

Ammonia is absorbed in large quantities by the chloride of phosphorus and of sulphur; and compounds are produced having singular properties.

Most metallic salts absorb ammonia when exposed to a current of the dry gas, and some metals are remarkable for the character that ammonia, when added to these solutions, produces precipitates which contain either ammonia or amidogene, as in the case of mercury; or by an excess of ammonia the precipitate is redissolved, and soluble compounds are produced containing ammonia, as in the case of zinc. The number of these compounds is very great, but the most interesting of them are the *ammonia salts of zinc, ammonia salts of copper, ammonia salts of nickel and of cobalt, ammonia salts of silver, and ammonia salts of mercury.*

Important compounds are formed by the action of ammonia upon the haloid salts of mercury. When chloride of mercury is heated in a current of dry ammoniacal gas, it unites with the gas, forming a white fusible and volatile compound, the formula of which is 2 Hg. Cl. + HAd.; by contact with water this body is resolved into sal-alembroth and white precipitate; the first a compound of sublimate and sal-ammoniac; the second a white powder, the constitution of which will be understood by attending to the following facts. If a slight excess of ammonia be added to a cold solution of corrosive sublimate, a copious white precipitate falls, and the liquor is found to contain half the chlorine of the sublimate combined with hydrogen and ammonia, as sal-ammoniac; the white powder, known to the earlier chemists as *white precipitate of mercury*, contains the mercury and the remaining half of the chlorine of the sublimate; it was supposed to contain ammonia and oxygen, but Dr. Kane has proved that it contains only the elements of amidogene, and no oxygen,—that it is, in fact, a chloro-amidide of mercury; it is insoluble in cold water, is decomposed by boiling water, and when suddenly heated is converted into calomel, nitrogen, and ammonia.

In all these cases ammonia enters into combination with acids, bases, haloid and oxygen salts, in a manner that assimilates it to chloride of hydrogen, and removes it from any analogy with alkalies, which in other respects it strictly resembles. The distinction is, that when it acts as an alkali, ammonia is associated with water. To explain the necessity of the presence of water a theory was proposed, according to which it was considered that the ammoniacal salts do not contain ammonia, but another compound of nitrogen and hydrogen, NH_4, which is metallic, and in all general characters like potassium; to this body the name of *ammonium* was given. The theory accords with experiment, as in every oxygen salt of ammonia there is as much water as may form with the ammonia oxide of ammonium ($NH_4. O$), and in every haloid salt the electro-negative body is combined with as much hydrogen as may convert the ammonia into the compound metal; thus. $NH_3. HO + SO_3.$ and $NH_3. + H Cl.$ would give $NH_4. O + SO_3.$ and $NH_4. Cl.$ The theory derived additional strength from the formation of a remarkable body called the *ammoniacal amalgam.* If the negative pole of a galvanic battery be constituted of a globule of mercury immersed in water of ammonia the mercury will increase to fifty times its volume, become semi-fluid and covered with warty excrescences, and finally so light as to float on water; no hydrogen is evolved from its surface, but oxygen is abundantly given off from the positive electrode. If the current be interrupted a copious disengagement of hydrogen takes place from the metallic body; ammonia also is given off by it, and it soon assumes its original shape; this decomposition may be retarded by cold, the pasty mass may be removed from the fluid, and at a temperature of 0° it will crystalize in cubes; if decomposed, when dry, over mercury, it evolves ammonia and hydrogen in the proportion of two to one by volume, which indicates that the mercury is combined with a body which consists of NH_4., and as the mercury loses none of its lustre the compound formed is an alloy, or, more properly, an amalgam, and NH_4. is of a metalic nature. These phenomena may also be observed by dissolving one grain of potassium in a 100 grains of mercury, and dropping the globule into a glass containing strong solution of sal-ammoniac; by the action of potassium and mercury on chloride of ammonium chloride of potassium and the amalgam, Hg. NH_4., are produced; the globule of mercury swells rapidly, and the amalgam has sufficient permanency to be examined.

Muriate of ammonia—sal ammoniac (Cl. H_2. Ad.). This salt was originally brought from Africa, but is now manufactured on a large scale from the ammoniacal liquor obtained by the destructive distillation of horns, bones, coals, and all such organic matters as contain nitrogen. By adding to the liquor muriatic acid in slight excess, and then evaporating and cooling, the sal-ammoniac is obtained in small crystals, which are purified from tarry matter by re-crystalization, and sublimed from cast-iron pots, placed in a furnace lined with fire-tiles, into leaden heads which are adapted to the pots. The salt is then a coherent hemispherical mass, and, if pure, is free from yellow stains and nearly transparent. It is very soluble in water; crystalizes both by sublimation and solution in cubes and octohedrons; it is slightly deliquescent, and is soluble in alcohol; it volatilizes below a red heat, and when heated with lime or potash it yields ammonia; its formula is H Cl., H Ad. being an equivalent of each element, by the direct union of which it may be formed. When equal volumes of dry muriatic acid gas and ammonia are mixed, the gases disappear and a snow-white powder of sal-ammoniac is formed. Sal-ammoniac enters into the composition of a great number of double salts.

Hydrosulphuret of ammonia is formed by passing sulphuretted hydrogen into water of ammonia. The solution turns yellow on exposure to the air, owing to the absorption of oxygen and liberation of sulphur which is held in solution.

Nitrate of ammonia ($Ad. H_2. O. NO_5.$) is formed by neutralizing nitric acid by ammonia; its crystals are striated hexagonal prisms; isomorphous with nitre; of a bitter saline taste; deliquescent and very soluble in water; when heated they fuse at 230°, and at about 460° are rapidly decomposed into nitrous oxide and water. When heated with combustible bodies this salt deflagrates violently.

The *carbonate of ammonia,* used medicinally, is prepared by subliming in a suitable apparatus a mixture of one part of sal-ammoniac with two of powdered chalk; chloride of calcium and carbonate of ammonia are produced. The sublimed salt is a crystaline semi-transparent mass, and was considered a sesquicarbonate, but it consists of two mixed carbonates; neutral carbonate of ammonia exists only in combination, and its compounds are very numerous.

CYANOGEN ($C_2. N.$, or Cy.).

THIS compound does not exist in nature ready formed, but it can be procured in an isolated state, and its compounds may be generated directly from it as if it were a simple body. The kernels of peaches, plums, bitter almonds, and the leaves of the cherry-laurel yield, by distillation, prussic acid, which is a cyanide of hydrogen. Cyanogen may be formed abundantly by bringing its elements together at a high temperature in contact with any substance with which it may unite; as when an organic substance containing nitrogen is calcined with potash the nascent carbon and hydrogen unite and cyanide of potassium is formed. Cyanogen may be generated in different ways. To obtain it pure, cyanide of silver is to be introduced into a small glass retort, and heated to just below redness; the cyanide is resolved into silver and cyanogen; the latter comes over in a gaseous form, and must be collected over mercury. Cyanogen is colourless; has a sharp smell, and irritates the eyes; its sp. gr. is 1819; it may be condensed by a pressure of about four atmospheres, and is then a colourless fluid; it is combustible, burning with a beautiful rose-coloured flame, and producing two volumes of carbonic acid and one of nitrogen; it consists of equal volumes of carbon vapour and nitrogen, the two volumes being condensed into one; it dissolves freely in alcohol and in water, but very complex changes soon take place in the solutions. Cyanogen combines directly with hydrogen and with the metals; with oxygen its combinations are indirect; these are three in number, all acids; it unites also with sulphur.

Fulminic acid ($Cy_2. O_2. + 2HO.$), remarkable for forming salts which detonate, is prepared by the action of nitric acid on alcohol, oxide of mercury or of silver being present; the products are numerous and the reaction very complex, formic, acetic, oxalic acids, &c., being formed.

Fulminate of silver ($Cy_2. O_2. + 2\ Ag\ O.$) is prepared by dissolving silver in ten parts of nitric acid, sp. gr. 1·35, and pouring the solution, when cold, into twenty parts of rectified spirits of wine; the mixture is to be gently heated till it begins to boil, and then left to cool slowly; fulminate of silver is deposited in fine silky crystals, snow-white, and of equal weight with the silver employed; it is sparingly soluble in cold water; it detonates by the slightest shock, or by contact with sulphuric acid. A more explosive compound is formed by dissolving this one in warm dilute nitric acid; half of the silver is removed and replaced by water: acid fulminate of silver crystalizes out of the liquor.

Fulminate of suboxide of mercury ($Cy_2.O_2. + 2Hg_2.O$), the most important salt of fulminic acid, is prepared by dissolving mercury in nitric acid, and treating it with alcohol, as in preparing fulminate of silver; when the solution cools metallic mercury and the fulminate of the suboxide are deposited; the latter in hard, opaque white, generally very minute crystals, which, when washed and re-dissolved in boiling water, crystalize in fine silky needles. This salt detonates when struck between two hard bodies, and is extensively employed in the manufacture of percussion caps.

Cyanide of hydrogen—hydrocyanic acid, or prussic acid ($C_2.N.H.$) may be formed by the direct combination of hydrogen and cyanogen; and it is found in the water distilled from bitter almonds, or from the leaves of the cherry-tree laurel, being produced from the decomposition of a substance, called *amygdaline*, contained in those plants. For practical purposes it may be prepared by several indirect processes. If vapour of formiate of ammonia ($C_2.HO_3. + NH_4.O.$) be passed through a red-hot porcelain tube it is converted into prussic acid and water ($C_2.N.H.$ and $4HO.$). By passing ammonia over red-hot charcoal hydrocyanate of ammonia is formed. For the preparation of it on a large scale, the yellow prussiate of potash of commerce is used. This salt consists of cyanide of iron united to cyanide of potassium; by the action of sulphuric acid three-fourths of the latter are decomposed, bisulphate of potash is formed, and prussic acid is liberated, the cyanide of iron remaining united to the other fourth of cyanide of potassium. Prussic acid is a colourless fluid; its sp. gr. at 67° is 0·6969; at 5° it congeals into a mass of fibrous crystals, and it boils at 80°; it imparts an evanescent red stain to litmus; it has a very pungent suffocating odour, resembling that of bitter almonds; its taste is bitter and acrid; it burns with a bright blue flame, and it is intensely poisonous. Anhydrous prussic acid decomposes rapidly, especially when exposed to light, forming ammonia and a brown substance, the composition of which is not well known; in contact with a strong acid it produces formic acid. For medical purposes this acid is prepared in a very dilute condition; that prescribed in the London Pharmacopœia contains about 2 per cent. of real acid, that in the Edinburgh Code about 4 per cent., and the Dublin preparation contains about 1·5 or 1·6 of acid. Prussic acid is easily detected; its solution gives with nitrate of silver a precipitate of white cyanide of silver; insoluble in strong nitric acid when cold, but soluble by boiling; it is soluble in ammonia. There are many other means of detecting it, all of easy application.

Cyanogen forms compounds with chlorine and iodine, and with the metals very numerous combinations; of these the following are the most important.

Cyanide of potassium (K. Cy.) may be formed by the direct union of its elements; or by adding an excess of acid to a solution of potash, and evaporating rapidly, without the access of air; it is also formed whenever carbonaceous matter is calcined in contact with potash, if nitrogen be present; the mass being digested in weak spirit of wine deposits cubic crystals on cooling.

Cyanide of mercury (Hg. Cy.) may be obtained by boiling two parts of prussian blue with one of red oxide of mercury and eight of water until the residue becomes red brown; cyanide of mercury is deposited in crystals from the filtered liquor. This salt forms compounds with alkaline cyanides, bromides, and chlorides. Prussic acid was formerly prepared from this substance.

Protocyanide of iron (Fe. Cy.) is not obtained in an isolated form, but it enters into combination with the other metallic cyanides forming double salts. As the iron in these salts cannot be separated by an alkali; it

STARCH, LIGNINE, GUM, SUGAR, AND THEIR PRODUCTS.

THESE substances exist in abundance in most plants, differing somewhat in character according to the plant whence they are obtained: they serve the most important uses in the vegetable economy, furnishing the material from which the tissues and secretions of the plant are elaborated. They have a similarity of constitution; all contain 12 atoms of carbon, united to oxygen and hydrogen in the proportions to form water. The changes of these bodies from one to another may be accounted for by the alteration in the proportions and chemical relations of the watery element, effected by the action of other bodies.

Starch is found in most plants, and in all parts of them; it is procured from the seeds of farinaceous plants, from the tubers of the potatoe, from the root of *jatropha manihot* as (*tapioca* or *cassava*), from the root of the *maranta arundinacea* (as *arrow root*), and from the stems of palms, as *sagus rumphii* from which sago is obtained. In the plant starch exists as small white grains, imbedded in the cellular tissue; these grains differ in size in almost every plant; those of the potatoe, which are the largest, do not exceed $\frac{1}{250}$ of an inch in diameter; those of arrow root, which are amongst the smallest, do not exceed $\frac{1}{600}$ .of an inch; they differ also in form, some being globular, some oval, and some irregular; each grain is formed by a number of concentric layers, increasing in density and consistence from the centre, the external one resembling a membranous bag filled by a softer substance. Grains of starch are insoluble in cold water, but are soluble in boiling, save the outer layers, which, floating in the fluid, impart to it the appearance peculiar to boiled starch; the solution gelatinizes on cooling; if it be dried at a gentle heat, and digested with cold water, a colourless transparent solution of starch may be obtained by filtration, which separates the outer layers.

Starch is converted into sugar by the vital action of the plant; this change constitutes the *saccharine fermentation*, which is artificially produced in the process of *malting* grain. When starch is heated above 240° it becomes soft and brown; if the heat be increased until the mass smokes, it is converted into a substance soluble in cold water, and is known under the name of *British gum*.

By the action of reagents starch is made to undergo many singular changes; by boiling with dilute sulphuric or muriatic acid, it is changed successively into gum, sugar, and a substance called saccharine; by boiling it with nitric acid, saccharine and oxalic acids are formed; but its most remarkable property is the production of a compound of an intense blue colour with iodine. The composition of starch in every instance is in symbols, $C_{12}. H_{10}. O_{10}.$, or 12 of carbon, 10 of hydrogen, and 10 of oxygen.

Inuline is a kind of starch found in the roots of the inula, dahlia, and many other plants; it is distinguished from common starch by its solution being tinged yellow by iodine.

Lichenine is a variety of starch found in many lichens, especially Iceland moss, and Irish moss, or *Carrigeen* (*spherococcus crispus*); it gives with iodine a greenish brown colour.

Woody fibre.—By treating wood successively and frequently in dilute acids and alkalies, in alcohol and in water, every soluble constituent of it is removed, and a substance remains, the composition of which is constant, and consists of $C_{12}. H_8. O_8.$; this is named lignine, and constitutes the wood, properly so called, of the plant: of it are formed the tubes and cells of the vegetable tissue, and the tough fibres of flax, cotton, and hemp. Lignine forms some compounds which are of great practical importance; thus, if linen or cotton cloth be dipped in a solution of a salt of alumina, the lignine unites with the alumina, setting the acid free, and thus serves to fix upon the cloth the various colouring matters used in dyeing; oxides of iron and of other metals have a similar, though weaker, affinity for lignine. Lignine when pure is white; the bleaching of linen, cotton, and of other substances formed by lignine consists in getting rid of the resinous and other colouring matters which exist in the fibres and cells of plants; this is effected by the action of air or of chlorine; the lignine itself resists the action of bleaching agents if not applied in a highly concentrated form. With cold nitric acid lignine forms a substance called *xyloidine;* it may be obtained by immersing a piece of paper in cold nitric acid, and then washing it well in pure water; it presents the feel and toughness of parchment, and burns like tinder. By the action of hot nitric acid lignine is converted into oxalic acid; by sulphuric acid it is converted into gum, and finally into sugar. By submitting sawdust for some hours to the action of a warm solution of potash, a considerable quantity of starch will be produced; pure lignine, however, contains none. Lignine remains unaltered for an indefinite time in dry air, or under water free from air; but when exposed to the action of air and water it absorbs oxygen; carbonic acid and water are given out, and those products are formed which constitute vegetable soil suited to the nutrition of plants.

Gum.—Of this substance to which the names of *arabine, cerasine,* and *dextrine* may be applied, the first two are natural products. *Arabine* exists in the juices of many species of acacia and prunus; exuding from crevices in the bark, it forms the *gum arabic* and *gum Senegal* of commerce; it is contained in large quantities in the roots of mallow and of many other plants; it is soluble in water but not in alcohol; it forms with bases insoluble compounds: by the action of sulphuric acid it is gradually converted into dextrine, and finally into sugar; with nitric acid it forms mucic acid, and afterwards oxalic acid; it gives a precipitate with silicate of potash: the formula of arabine is $C_{12}. H_{11}. O_{11}.$ *Tragacanthine,* or *vegetable mucus*, is found in cherry-tree gum mixed with arabine, but exists purer in gum tragacanth, in flax seed, and in quince seed; it forms a tenacious fluid with water, which it appears to combine with rather than dissolve in; it is precipitated by basic acetate of lead, and by alcohol, but not by silicate of potash; with sulphuric and nitric acids it forms the same products as arabine. *Salep* is dried tragacanthine, obtained from the roots of various species of orchis. *Dextrine* is formed from starch in germination, and may be obtained by treating starch in dilute sulphuric acid; when dried it is a pale yellow mass of a vitreous fracture; it is not adhesive; it is precipitated by a solution of basic acetate of lead, but not by silicate of potash; its composition is $C_{12}. H_{10}. O_{10}$.

Sugar.—There are various species of sugar, all characterized by being capable of undergoing the alcoholic fermentation. Of these the most important is *cane sugar*, the composition of which, when crystalized, is $C_{12}. H_{10}. O_{10}$., and ten atoms of water; it is found in the juices of many plants, and for commercial purposes is extracted from the sugar cane, the maple, and the beet-root. Pure cane sugar is colourless; its sp. gr. is 1·6; it fuses at 350° into a clear yellow, and congeals on cooling into a hard brittle mass, which after some weeks becomes opaque, white, and crystaline. At a heat of 630° sugar gives off water, and is changed into a substance called *caramel;* at a higher temperature it is entirely decomposed; it dissolves in three parts of cold water, and in all proportions in boiling water; a saturated solution solidifies when cooled; a strong solution of sugar, when kept for some time near its boiling point, is gradually converted into uncrystalizable sugar, which is a source of loss in its manufacture. Sugar is sparingly soluble in absolute alcohol, and moderately in weak spirit; it combines with some bases and salts, acting as a feeble acid. By the reaction of acids upon sugar substances are produced which have received the names of *glucose*, *sacchul-*

mine, sacchulmic acid, saccharic acid, caramel, and *metacitone.*

Grape sugar, or *glucose,* is formed when in crystals of $C_{12}.H_{11}.O_{11}.$ and 3 atoms of water; it is more extensively distributed in nature than cane sugar; it imparts the sweet taste to fruits, and forms the solid part of honey; it is formed in the animal body when affected with the disease called diabetes; it may be prepared from starch, gum, or cane sugar, by the action of SO_3. To convert lignine into sugar, bits of paper or of linen are to be treated with their own weight of oil of vitriol, till they are converted into an uniform viscid mass, avoiding heat; this is to be diluted, and the liquor boiled for some time, the acid being removed by chalk: sugar is obtained by crystalization. Glucose, as it is termed by Dumas, crystalizes in hard colourless tables, or in grains of closely aggregated needles; its sp. gr. is 1·38; it is much sweeter than cane sugar, and less soluble in water.

Lignine, starch, gum, and cane sugar, contain each the same quantity of carbon, so that their conversion into grape sugar may be assumed to depend on the fixation of the elements of water; thus lignine consists of $C_{12}.H_8.O_8.$, and takes 4 HO. (water); 100 parts of sawdust give 115 of sugar. Starch $C_{12}.H_{10}.O_{10}.$ takes 2 HO., and 100 parts of it yield usually 106 of glucose.

Lactine, or *sugar of milk,* is a substance found only in the milk of the mammiferous class of animals; it is prepared by evaporating whey to a pellicle and setting it aside to cool, when the sugar crystalizes in small square prisms, white, semitransparent, hard, and gritty.

Mannite, the sweet principle of manna and *glycyrrhizine,* though allied in properties to the sugar, differ from it materially, in not being capable of undergoing alcoholic fermentation.

Alcohol.—If a watery solution of sugar be exposed to the action of the air it is gradually decomposed, becoming brown and sour; if it be brought into contact with any organic substance undergoing slow decomposition, carbonic acid and alcohol will be formed. The active ingredient in this fermentation is *yeast*, an azotised body; the property, however, is common to a great many animal and vegetable substances, of which the most important for the purpose of fermentation are vegetable albumen and gluten. These exist more or less in all fruits and seeds, differing in character according to the source whence they are derived. When wheaten flour in a linen bag is washed with water, starch is removed and a tenacious paste remains, which consists of albumen and gluten mixed; by boiling in alcohol the gluten is dissolved, from which solution it is precipitated by water, and may be collected and dried; it is pale yellow, forms when soft an adhesive very elastic mass. Vegetable albumen is inelastic, and when dried forms a hard white mass. In peas and beans a substance is found which possesses properties intermediate to those of the gluten and albumen of wheat; this is called *legumin*. These bodies differ from most vegetable substances in containing a large quantity of nitrogen, and in the case of legumin sulphur is also a constituent; when burned they leave an ash similar to that of animal substance. In contact with air and water these vegeto-animal bodies are spontaneously decomposed; carbonic acid, ammonia, and other products are generated; and the particles of sugar in contact with them are involved in alcoholic fermentation. From this action the sugar is protected while in the investing membrane of the fruit-cells; but when these are broken up oxygen is absorbed, the vegeto-animal matter undergoes decomposition, and alcoholic fermentation is superinduced on the sugar. Oxygen is necessary only at the commencement of the decomposition, for if the putrefaction of the albumen or gluten have commenced, it will extend throughout the mass without further action of the air. *Artificial ferment*, or *yeast*, is a decomposing mass of vegetable gluten or albumen. By distilling any saccharine solution that has undergone this fermentation alcohol is obtained: by repeated distillation it is deprived of most of the water which at first comes over with it. In the diluted form it constitutes the various spirits of commerce, and in the more concentrated state is called *spirit of wine*, or *rectified spirit*. Alcohol cannot be entirely deprived of water by distillation merely; when of sp. gr. 0·813 at 60° it contains 8·2 per cent. of water, its boiling point is 172°, and it distils over unchanged; the proof spirit of commerce is of sp. gr. about 0·920, and contains 48 per cent. of absolute alcohol; rectified spirit contains about 83 per cent. of alcohol, and has a sp. gr. of 0·839 at 60°. To obtain absolute alcohol, rectified spirit is distilled at a moderate heat over some substance having a stronger affinity for water than the alcohol has; of these, dry chloride of calcium is the best. Anhydrous alcohol has a sp. gr. of 0·7947 at 60°; it boils at 168°; the most intense cold does not congeal it; its taste is dry and burning, as it abstracts water from the tongue; it is highly inflammable, burning with little light; if some drops of it are poured into a jar of oxygen gas, its vapour will form a very explosive mixture; it mixes with water in every proportion, contracting in volume and evolving heat; the greatest condensation occurs with 54 volumes of alcohol and 50 of water, a mixture of which occupies only 100 volumes. The formula of alcohol is $C_4. H_6. O_2$.

Ether may be prepared by any process which deprives alcohol of the equivalent of water which it contains; thus, by distillation with chloride of zinc, and by a variety of other processes, alcohol is deprived of water and ether obtained. On the large scale ether is obtained by action of sulphuric acid upon alcohol; a mixture of equal weights of rectified spirit of wine and of oil of vitriol are distilled from a glass globe at about 260°; ether comes over with some water and unaltered alcohol; as the distillation proceeds the quantity of sulphuric acid exceeds that of the alcohol, upon which its action is altered; the mixture becomes darkened in colour, a substance distils over called *oil of wine*, and the formation of ether is diminished: Sulphurous acid and olefiant gas are evolved, and the mixture becomes thick and black, and froths up. By the addition of a small but continuous stream of rectified spirit these reactions may be avoided. The production of ether is stated to depend upon the formation of sulphate of ether, water being set free; but when heat is applied the ether is expelled from the acid with which the water recombines. Ether is freed from its impurities by rectification over dry carbonate of potash. It is a colourless liquid, having an agreeable penetrating odour, and a pungent taste; its sp. gr. is 0·720 at 60°; it freezes at — 47°, and boils at 96°; it is very combustible; its vapour diffused through air or oxygen forms very explosive mixtures; exposed to the air, it gradually forms acetic acid, absorbing oxygen from the air; its formula is $C_4. H_5. O$.

There are several other ethers, the composition of which consists in a mixture of the acid employed in their preparation with other elements; thus, nitric ether is composed of hyponitrous acid with the same elements as exist in sulphuric ether. The various compounds of ether are too numerous to admit of examination here.

Olefiant gas is one of the products of the action of sulphuric acid upon alcohol; the alcohol, in the first instance, losing an atom of water, is converted into ether, which, by the action of the excess of sulphuric acid, is deprived of the elements of another equivalent of water, and olefiant gas is the result—$C_4. H_5. O.$ yielding $C_4. H_4.$ and HO. This gas is generated in large quantity by the decomposition of coal, pitch, oil, &c., at a red heat, for the purpose of illumination. It is colourless when pure, and burns with a brilliant white flame, producing much smoke; its sp. gr. is 980·8; two volumes of it combine with two of vapour of water to form alcohol, and with one of vapour of water to form ether.

Acetic acid. The conversion of alcohol into acetic acid consists in the removal of two atoms of the hydrogen of the alcohol and the addition of two atoms of oxygen. These actions are successive, and a substance called *aldehyd* is intermediate between the two, the formula being thus: alcohol, $C_4. H_6. O_2.$, by losing $H_2.$ gives aldehyd $C_4. H_4. O_2.$, and this last, by taking $O_2.$, gives hydrated acetic acid, $C_4. H_4. O_4.$ Dilute acetic acid is obtained by distillation from the vinegar of commerce; concentrated acetic acid is obtained by the decomposition of its salts by a stronger acid; as by distilling one part of dry acetate of soda with two parts of oil of vitriol. This acid is recognised by its volatility and peculiar odour; it has a decided acid reaction; its solutions are precipitated by the nitrates of silver and black oxide of mercury, forming white crystaline salts sparingly soluble in water; it combines with all the bases forming salts; generally very soluble and crystalizable; of these the most important are the acetates of soda, potash, barytes, lime, alumina, zinc, iron, lead (*sugar of lead*), copper (*verdigris*), mercury, and silver.

Light carburetted hydrogen—marsh-gas, is produced by the decomposition of organic matter at a high temperature; it is always found in coal-gas used for illumination. It may be formed by passing olefiant gas through a red-hot tube, by which half of its carbon is deposited. One important source of this gas is the decomposition of vegetable matter in contact with water and excluded from the air. It constitutes the *fire-damp* of coal-mines; its formula is $CH_2.$; its sp. gr. 559; it burns with a yellow flame, and has but little illuminating power.

Essential oils are so named from their volatile nature and from their alcoholic solutions, constituting what are called *essences*. They are obtained from the plants in which they exist by distillation with water, as distillation from the dry plant would alter their properties; these oils distil over mixed with watery vapour. The various *medicated waters* are formed by being impregnated in a slight degree with the odour and properties of these oils.

Most of the essential oils exist in the plant; some are produced at the moment of distillation by the decomposition of substances which did exist in the plant, as in the case of oil of bitter almonds and oil of mustard. Some essential oils by attracting oxygen produce well-defined acids, whilst others, by uniting with oxygen, form resins. One of the most remarkable of the essential oils is that of mustard, being constituted of five elements, as follow: $C_{32}.\ H_{20}.\ N_4.\ S_5.\ O_5.$ Of the essential oils some contain oxygen and some do not.

Camphor. This substance is extracted from the wood of the laurus and dryobalanops camphora by distillation with water; its formula is $C_{20}.\ H_{16}.\ O_2.$; its properties are familiarly known.

Resins in composition and properties resemble camphor; but they are not volatile; without decomposition, and generally capable of assuming acid properties.

Amber. A substance bearing resemblance, in many respects, to the preceding, is found cast on shore on the coast of the Baltic, and in connexion with fragments of decomposing wood in the lignite beds of the north of Europe; it appears to be a turpentine secretion of some unknown trees of an early geological epoch; it consists of a mixture of two resins—a volatile oil and *succinic acid.*

Fats and oils are found extensively both in the animal and vegetable kingdoms. They are mixtures, as they exist in nature, of fatty and oily bodies in variable proportion; the majority of fats consist of two simple fats—*stearine* and *margarine*, and a simple oil called *olein*. These fatty substances are termed *fixed*; that is to say, they cannot be distilled without decomposition; exposed to the air they attract oxygen and evolve carbonic acid, and, at the same time, obtain an acid reaction, and a peculiar smell, called *rancid*. The most important property of fixed oils and fats is that of forming soaps with alkalies. The soap is a true salt formed by the conversion of the fats or oils into acid which unites with the alkaline base.

Organic acids naturally existing in plants. Of these acids the most generally found and most important are *tartaric acid* ($C_8.\ H_4.\ O_{10}.$ + 2 of water), *citric acid* ($C_{12}.\ H_5.\ O_{11}. + 3\ HO$ + 2 of water), and *malic acid* ($C_8.\ H_4.\ O_8. + 2\ HO.$). Tartaric acid exists in most fruits, sometimes free, but generally combined with potash, forming *cream of tartar,* or a tartrate of lime; for commercial purposes it is prepared from bitartrate of potash (cream of tartar). This salt exists in abundance in grape-juice, and, being but sparingly soluble, it is deposited on the insides of the casks in which wine is made. This important pharmaceutic preparation, *tartar emetic,* is a tartrate of potash and antimony ($C_8.\ H_4.\ C_{10}. + KO.\ Sb\ O_3.$ + 2 of water). This acid combines with bases forming many other important salts. *Citric acid* exists in the juices of fruits, especially in those of the lemon, orange, currant, and quince; it is generally prepared from lemon-juice. *Malic acid* exists in most fruits along with citric and tartaric acid; it is found purest and most abundant in the berries of the mountain ash, and in the house-leek.

Tannic acid, or *tannin* ($C_{18}.\ H_5.\ O_9. + 3\ HO.$), exists in the bark of most trees of the exogenous structure, and in the greatest quantity in oak and chestnut, chiefly in the inner layers of bark; it is also found in the roots and leaves of some plants; but its most abundant source is the gall-nut of the *quercus infectoria,* a species of oak. The watery solution of this acid reddens litmus; its taste is very astringent, but not bitter. The most important property of tannic acid is its combining with animal gelatine to form a substance insoluble in water, which constitutes the basis of most kinds of leather. An infusion, or tincture of galls, is used in the laboratory as a re-agent, and in certain photographic processes; it does not affect the solutions of zinc, cadmium, protoxides of iron, manganese, nor of any of the alkaline or earthy salts; with solutions of lead and antimony it gives a white precipitate; with copper grey; with tin, nickel, cobalt, silver, &c., yellow; with bismuth orange; with platinum green; with gold brown; and with peroxide of iron blueish purple. The last decomposition constitutes the basis of writing-ink.

THE END.

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